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PETROLEUM TECHNOLOGY DEVELOPMENT IN LIBYA: DEVELOPING AN EVOLUTIONARY MANAGEMENT FRAMEWORK

by

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DEDICATION

This work is dedicated to

souls of my parents Ali and Fatima

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Significance of technology as a vital element of petroleum industry can not be overstated. It is no longer an issue that is greatly expanded within the last decades and considered a fundamental factor for success of all upstream and downstream petroleum activities. Now, more than ever, petroleum organizations worldwide rely on technology to improve efficiency of technical operations and quality of petroleum products, as well as to reduce costs of finding oil and gas.

Over many decades, Libya has been considered a key player in producing and exporting oil to the world, and yet likely to become world- recognized country in both upstream and downstream sectors through its continuous dedication to extend exploration activities all over the geographical areas of nationwide, and to promote production and processing capabilities to meet its strategic goals of oil and gas. In this sense, technology of oil and gas can play an essential role to accomplish effectively all of these business challenges and lessen scale of associated risks.

Throughout nearly fifty years, the Libyan oil industry has experienced many technical development stages that based essentially on western technology involvement. In view of that fact, all exploration, production and processing facilities which have been established and being upgraded in Libya are entirely dependent on abroad technologies, specifically from North America and Western Europe. Besides, all indigenous skills obtained along that period of time are mainly accumulated in terms of operating, managing, and maintaining of those technological facilities, with no real role for in-house research efforts to create successful technological innovations which could be exploited to solve petroleum problems, support oil and gas development strategies, and help building national catching-up capacity.

Hence, this study sheds light on this concern, and aims at originate a management framework for technological catching-up by developing an empirical understanding of technology development implications in Libyan oil sector, and through exploring the experiential stock of research organizations, firms and business sectors involved in technological innovation in both industrialized and developing countries.

Chapter One

THE RESEARCH PROBLEM IN PERSPECTIVE

"The formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle require creative imagination and marks real advance in science."

Albert Einstein

1. THE RESEARCH PROBLEM IN PERSPECTIVE

1.1 INTRODUCTION

For oil industry, technology is a major factor for success of both upstream and downstream operations. At micro-level, operating firms, technology suppliers and associated research laboratories challenge, nowadays more than ever, the demand for developing more petroleum technology in order to solve numerous technical problems arise day-to-day during the exploration, production and processing activities. Technological challenges, in this regard, extend also to meet future development plans of hydrocarbon projects and lessen the scale of business-associated risks.

Energy consumption is soaring today as never before driving the global demand for more energy production. Quenching the world's thirst for energy will call for more technological investments. This may urge Libya, as being oil & gas producing country, to get involved in some technological ventures in order to explore and produce efficiently its considerable hydrocarbon potential. Technological advancement for various oil and gas operations in Libya depends on the potential competence of Libyan oil industry to acquire and develop petroleum technological knowledge, the pattern and the defined prerequisites of technological capacity building, and the impact of national government policies on the building blocks of innovation system.

Process of technological innovation comprises a set of arduous brainstorming efforts to translate ideas and scientific knowledge into physical applications that have socio-economic impacts. Equation of innovation chain requires integration of knowledge and expertise to attain the scientific invention, entrepreneurial spirit and supportive environment to commercialize that invention, and management skills to plan technological strategies, allocate resources and control relevant costs and timing of technology introduction. Hence, for developing countries aim at technological catching-up, such equation of innovation is much significant to draw a considerable attention in order to realize its main components and dimensions.

Ambitions of developing countries for technological catching-up are increasingly rooted in their commitment and competence to rapidly build up capabilities. This places national knowledge systems at the core of technological development strategies. As a result of the cumulative nature of learning and differences in the rate of accumulation of technological capabilities, there is an inherent expansion in the economic prosperity gaps across the developing countries comparing to their industrialized counterparts. Narrowing these gaps requires sustainable catching-up efforts of various kinds. Pivotal among these is the swift accumulation of technological capabilities within a deliberate management framework for technological catching-up.

Libya, along with most developing countries, is suffering a catching-up capability weakness. Its national petroleum sector has experienced, over many decades, numerous technical development stages that based essentially on western technology involvement. In view of that fact, all exploration, production and processing facilities which have been established and being upgraded in Libya are entirely dependent on abroad technologies, specifically from North America and Western Europe. Besides, all indigenous skills obtained along that period of time are mainly accumulated in terms of operating, managing, and maintaining of those technological facilities, with no real role for in-house research efforts to create successful technological innovations which could be exploited to solve petroleum problems, support oil and gas development strategies, and help building national catching-up capacity.

Therefore, this research work sheds light on this concern, and aims at originate a management framework for technological catching-up by developing an empirical understanding of technology development implications in Libyan oil sector, and through exploring the experiential stock of research organizations, firms and business sectors involved in technological innovation in both industrialized and developing countries.

Structure of this study is designed to articulate in chapter one the perspectives of the research problem in terms of the problem statement, the research guiding questions, the research argument, the research key objectives, importance of study, the scope of empirical survey, the research process and the research determinants.

The literature review is exhibited in chapter two. Key research gaps that relate to technology development issues have been revealed such as weakness and inadequacy of innovation system approach, and an interactions gap of technological absorptive capacity. A comparative study of science and technology strategies for an arbitrary mix of some industrialized and developing countries is taken place in order to determine the common essentials for developing technology.

A broad understanding to the essentials of successful petroleum technology development has been built in chapter three through elaborating the implications of technological innovation dynamics at micro-level.

The Libyan petroleum industry is overviewed in chapter four. The sections demonstrate impact of hydrocarbon on national economy, oil and gas reserves, petrochemical exports, petroleum licensing agreements, manpower structure, fiscal turnovers, characteristics of upstream and down stream industries and research and development activities in Libyan petroleum institute.

The research methodology is elaborated in chapter five. The successive sections reveal; the basis on which the research paradigm and the logical principles have been selected, the thought process of reasoning the research problem, and the fundamental choices to determine the appropriate research approach that matches nature of the research problem. Methods of data collection and analysis, the design of measuring instrument, and validity and reliability improvement are addressed at the last section.

Data analysis and research findings are addressed in chapter six through examining the internal consistency reliability of constructs used in data analysis, univariate analysis of data variables in terms of descriptive statistics and exploratory data analysis, and multivariate analysis of data variables to explore differences and associations by use of parametric and nonparametric techniques. The last section addresses the research findings and extracts some areas for consideration in which the postulate management framework for technology development are rooted.

The management framework for technology development (MFTD) is synthesized and described in chapter seven, and its key elements are demonstrated in terms of targeting strategic technological opportunities, generating technological knowledge, turning ideas into business, driving innovation business and monitoring innovation performance. Eventually, chapter eight addresses the final conclusions, recommendations and future work.

1.2 THE RESEARCH PROBLEM

1.2.1 The Problem Statement

Technology is a key resource for corporate profitability and growth. It plays a considerable role for the well-being of countries, nations' technological self-reliance and effectiveness of international competitiveness. Nowadays, the significance of technology as a vital element of oil and gas industry can not be overstated. It is no longer an issue that is greatly expanded within the last decades and considered a fundamental to the success of all upstream and downstream petroleum activities. Today, more than ever, the petroleum organizations worldwide rely on technology to improve the efficiency of technical operations and the quality of petroleum products, as well as to reduce the cost of finding oil and gas.

Over many decades, Libya has been considered a key player in producing and exporting oil to the world, and yet likely to become world- recognized country in both upstream and downstream sectors through its continuous dedication to extend exploration activities all over the geographical areas of nationwide, and to promote production and processing capabilities to meet its strategic goals of oil and gas. In this sense, technology of oil and gas can play an essential role to accomplish effectively all of these business challenges and lessen the scale of associated risks.

Throughout nearly fifty years, the Libyan oil industry has experienced many technical development stages that based essentially on western technology involvement. In view of that fact, all exploration, production and processing facilities which have been established and being upgraded in Libya are entirely dependent on abroad technologies, specifically from North America and Western Europe. Besides, all indigenous skills obtained along that period of time are mainly accumulated in terms of operating, managing, and maintaining of those technological facilities, with no real role for in-house research efforts to create successful technological innovations which could be exploited to solve petroleum problems, support oil and gas development strategies, and help building national catching-up capacity.

1.2.2 The Research Questions

This research is guided by some questions, which should find appropriate answers at the end of this study, namely:

– *Empirically*: How to explain, why petroleum technology is not developed successfully in Libya? And what sort of considerations should be taken for remedy?

– *Theoretically*: At an industrial sector of developing country what makes developing successful technology possible? In particular, 1) How can strategy of technology development be set? 2) How can technological capacity for catching-up be properly built? 3) How can implications of knowledge generation and technology dynamics be handled? 4) How can innovation performance be monitored and controlled? 5) How such industrial sector can incorporate into international arena of technological development? Moreover, 6) what sort of scientific contribution can this research add to the realm of technology management?

1.2.3 The Research Argument

The concept of "*innovation systems*" either in terms of national or sectoral domain has been increasingly attaining attractiveness as a core conceptual framework for technological change that typically enhances economic growth of the nations. Many scholars from different academic disciplines centre largely on analyzing the systems of innovation in developed countries, but comparatively only a few studies focus on the systems of innovation in developing countries. The research argument herein is based on the idea that: Traditional frameworks of innovation systems such as "*national systems of innovation*" (NSI) and "*sectoral systems of innovation*" (SSI), focus principally on analyzing the innovation systems at macro-level of developed countries in order to maintain or improve an already established level of competitiveness and growth (Gu, 1999; Intarakumnerd et al. 2002; Feinson, 2003). These traditional frameworks, which are founded essentially on "*structure-based approach*" (i.e. the system is structured by some building blocks including knowledge, actors, institutions, and interactions), are not sufficient alone to address problems of technological innovation in developing countries. The specific nature of innovation systems and its related issues in developing countries (e.g., catching-up concern, weak competitiveness level) is different from the developed counterparts. In this sense, a further technological innovation framework has been originated in this study to meet the requirements of technological catching-up in developing countries at both macro & micro levels based on *"activity-based approach"* which includes the main causes and determinants of technological development.

1.3 KEY OBJECTIVES OF STUDY

This research work aims essentially to meet the following objectives:

– To originate a novel management framework for technological catching-up rooted in activity-based approach.

– To contribute scientifically through the research findings to develop new relations between some concepts of interest, and to integrate new concepts into the theoretical field of technology management.

1.4 IMPORTANCE OF STUDY

The potential outcomes of this study will contribute effectively to:

– Enhance the strategic management perspective of technology development in Libyan oil sector, once these outcomes taken sincerely into account of policy making, as this study addresses deliberately in terms of systematic approach some vital topics of technological catching-up such as targeting the strategic technological opportunities, capacity building, knowledge creation, idea generation, turning ideas into business, boosting of innovation environment, monitoring of innovation systems, etc.

– Increase stock of knowledge about implications of technology development at industrial sector of a developing country, namely: 1) Involvement of various organizations in research and development (R&D). 2) Organizations' R&D priorities 3) Organizations' R&D dependency. 4) Modes of generating R&D ideas. 5) Utilized models of technology development. 6) Structure of R&D facilities. 7) Rate of scientific and technical output. 8) Competency for technology assimilation. 9) Patterns of inward technology transfer. 10) Dependency on foreign supplier. 11) Characteristics of training programs. 12) Significance of petroleum technology development to policy makers. 13) Barriers to successful R&D projects and barriers to technology development. 14) Government willing to support intramural technology development. 15) Interactions between technology-related actors.

– Develop a better understanding on characteristics of research environment and features of technological team competency at sectoral level of a developing country, namely: 1) Job satisfaction. 2) Interpersonal relationships. 3) Information and communication process. 4) Organizational culture. 5) Learning climate. 6) Effectiveness of managerial system. 7) Technological absorptive capacity. 8) Capability for conceptualization.

– Broaden the understanding about characteristics of foreign support to technological innovation in a developing country in terms of: 1) Type of foreign direct investment (FDI). 2) Modes of FDI entry. 3) Barriers to FDI for technology development. 4) Priorities to encourage FDI for technology development.

– Promote the theoretical foundations of technology management in developing countries since; in fact, there is a handful publications pays attention to this concern (see Zawislak and Marins, 2007). Moreover, it is traditionally considered that strengthening the innovation environment in one business sector (e.g., Libyan oil sector) will enhance significantly the process of knowledge creation and dissemination, and influences by means of interactions and institutional arrangements the other related sectors of national innovation system.

1.5 THE RESEARCH CONFIGURATION

1.5.1 Scope of Empirical Study

The empirical study pays a substantial attention to the following principal areas:

– The Libyan petroleum sector including its indigenous and expatriate key players as a basis to study the concepts, technological characteristics and some related implications of sectoral innovation system in Libya as being a developing country.

– The technological competence domain in Libyan petroleum sector, which comprises: 1) Libyan Petroleum Institute (LPI). 2) National companies of oil producing, processing, and technical services. 3) Research community personnel.

– The technological interaction domain with Libyan petroleum sector, which includes: 1) Foreign oil companies, 2) National public universities and research institutes having relationships with the Libyan petroleum industry. 3) National private companies of technical oil services.

Figure 1.1 shows technological development domains in Libyan petroleum sector.

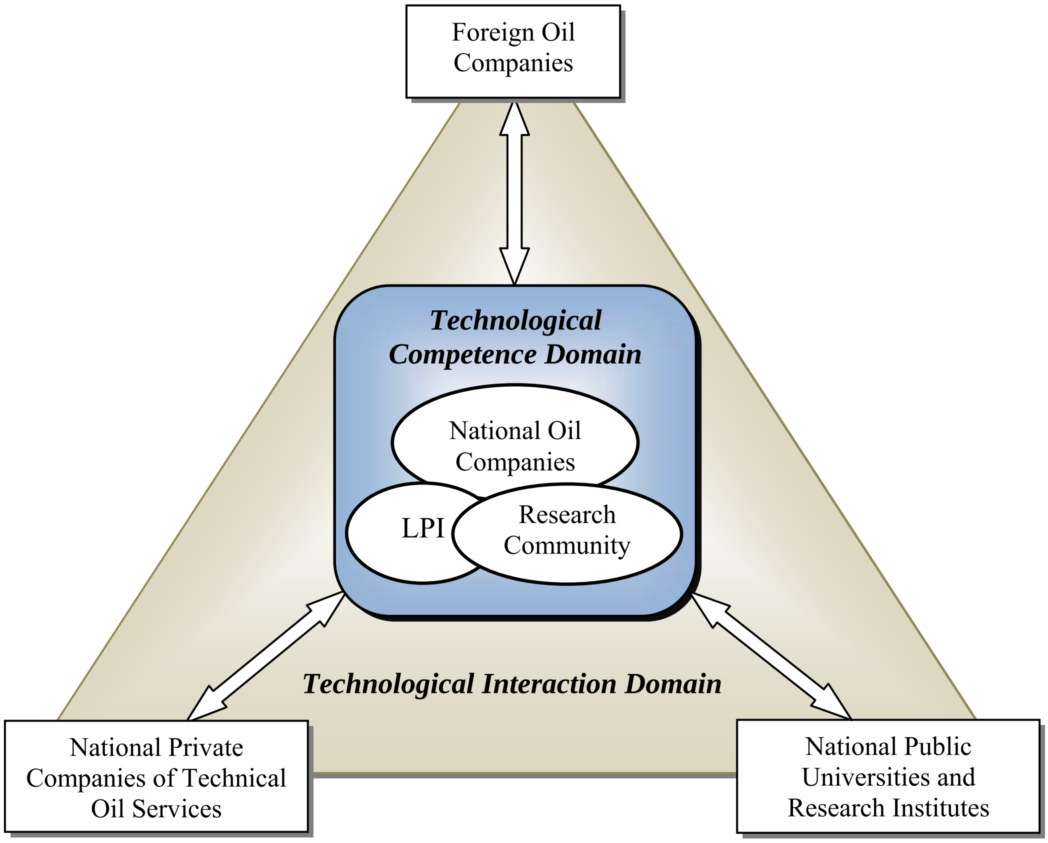


Figure (1.1): Technological Development Domains in Libyan Petroleum Sector

– Unit of analysis considered in this study encompasses unit of analysis at *organization-level* and unit of analysis at *individual-level*. The former is used to explore the organization technological capability and interactions, whiles the latter is deployed to investigate the human competency and behaviour as well as features of research environment.

– The study is designed to capture some secondary data concerning employment structure, finance distribution and training schemes in Libyan oil industry for a period of 2005-to-2007.

1.5.2 The Research Process

The research process framework for this study is depicted in figure 1.2.

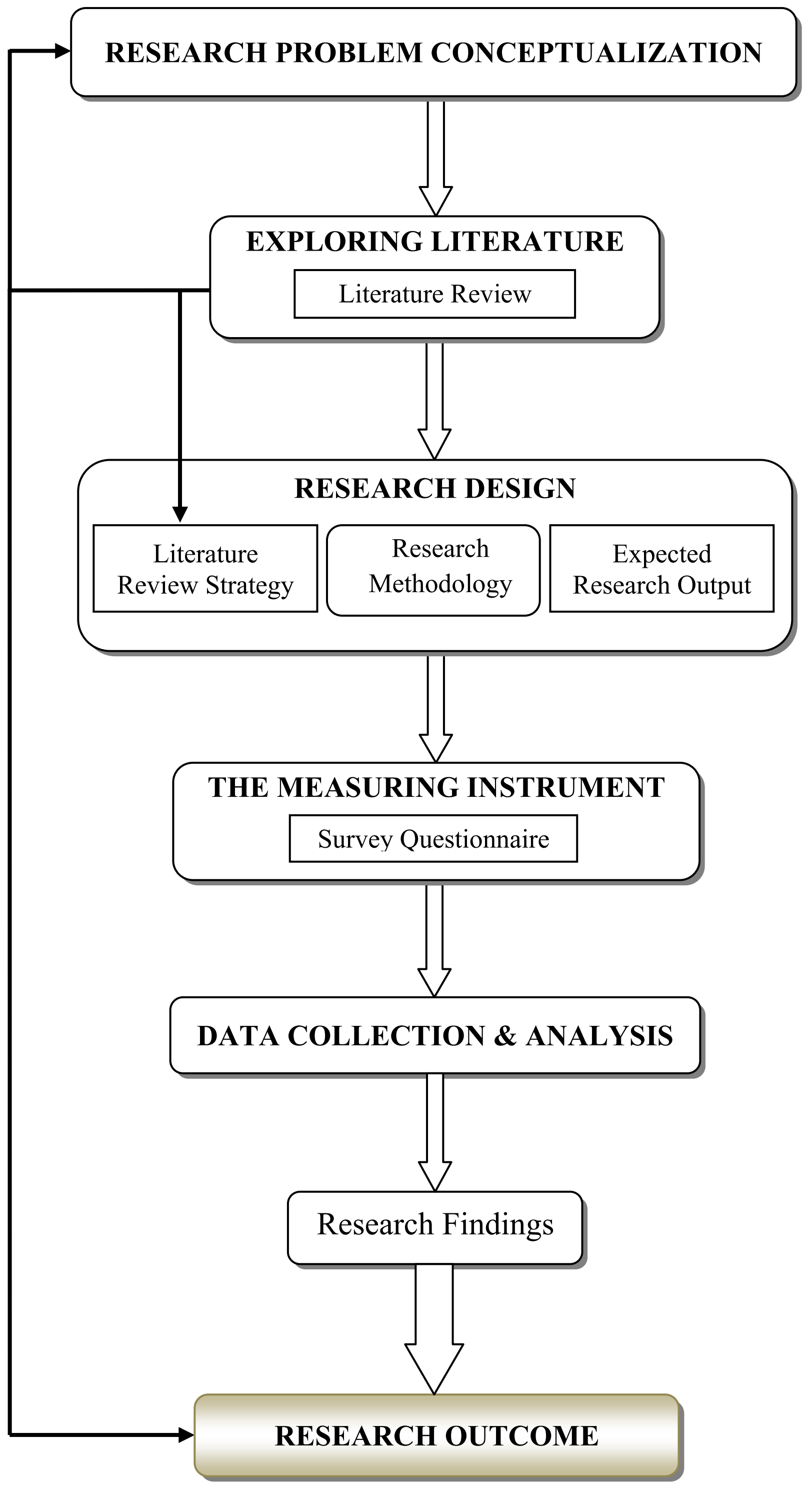


Figure (1.2): The Research Process Framework

This research process is designed to comprise the following activities:

– *Research Problem Conceptualization:* This is the research getting started activity, by which some related issues can be highlighted, namely: 1) Defining the research problem. 2) Arising the research questions. 3) Generating the research idea.

– *Exploring Literature:* In this step the literature review is taken place to: 1) determine the research needs and gaps, 2) sustain the research problem formulation, 3) design the literature review strategy which aims at determining the areas and scope of searching, and 4) help formulating the postulate management framework.

– *Research Design:* The setting up of research methodology is the most vital step in this regard which encompasses: 1) Epistemological foundations to establishing the validity and legitimacy of research work. 2) Method of data collection. 3) Method of data analysis. 4) Design of measuring instrument. 5) Validity & reliability measures. In this sense, the research design may include, along with the research methodology, the literature review strategy and the expected research output.

– *Measuring Instrument:* The survey questionnaire is the measuring instrument in this study, by which the phenomenon under consideration can be investigated. Piloting the measuring instrument is carried out in the course of this step.

– *Data Collection and Analysis:* The research data can be collected and analysed throughout this activity by using numerous scientific methods and techniques.

– *Research Outcome:* Obtaining the research findings can lead to finalize the research outcome (i.e., the management framework of technology development) which in turn expresses in essence the research scientific contribution.

1.5.3 The Research Determinants

This research is made up of the following determinants:

– *The literature Review*: This stage aims at: 1) Realizing the nature and extent of problem to be investigated in order to formulate the research questions. 2) Understanding the fundamental definitions, concepts and theories that underpin the research. 3) Determining the scope, context and parameters necessary for the research work. 4) Identifying the potential scientific contribution that might be added to bridge unmet research gaps. 5) Delineating the strategy of literature review. 6) Gathering some secondary data in relation to research scope.

Searching the literature in this study is designed, in addition, to: 1) Review the literature of technology management at organization-level. This includes reviewing some topics such as strategic management of technology, technology dynamics and forecasting, managing of technological innovation, principles of knowledge management, development of technological capabilities, etc. 2) Review the literature of technology development at state/sector-level in terms of science & technology frameworks (strategies/policies) in a mix of particular countries.

The entire searching process has been executed essentially across numerous references such as scientific books of various related topics, research papers of international journals, scientific articles, conference proceedings, annual reports of many petroleum organizations, statistical bulletins of petroleum industry, publications of sound international organizations, internal records of relevant departments, electronic data bases, etc.

– *The Exploring Process of Technological Competence of Libyan Petroleum Sector*: A questionnaire survey (see appendix A) has been developed and conducted entirely by the author himself over a period of one year in an attempt to explore the competence of Libyan oil sector to develop technology. This survey has divided mainly into seven parts, namely: 1) *Part one*, dedicated to survey the technology development competence at Libyan Petroleum Institute (LPI) by questioning the top policy makers. This part encompasses a qualitative questionnaire of twenty three questions and data collection form of ten inquires. 2) *Part two*, devoted to survey the technology development competence at national oil companies of overwhelming public ownership such as upstream companies, downstream companies and companies of technical oil servicing, through questioning the firms' board of directors. This part contains a qualitative questionnaire of twenty three questions. 3) *Part three*, dedicated to realize the characteristics of technological team competency and features of research environment in Libyan oil sector through interviewing the research community personnel. This part includes a qualitative questionnaire of fifteen questions. 4) *Part four*, committed to recognize the feature of interactions made by foreign oil companies to support developing the technology in Libyan oil industry in terms of inward foreign direct investment. This part contains a qualitative questionnaire of seven questions and dedicated to questioning the firms' top executive managers. 5) *Part five*, centred actually to survey the interaction of national universities and research institutes of public ownership with Libyan oil industry towards developing the petroleum technology. This part contains a qualitative questionnaire of eight questions, and devoted to questioning the organizations' scientific boards. 6) *Part six*, is to identify characteristics of interactions between national companies of oil technical services in private sector and Libyan oil industry towards petroleum technology development**.** This part contains a qualitative questionnaire of nine questions and mainly directed to interview the companies' top managers. 7) *Part seven*, surveys some quantitative secondary data of Libyan oil sector regarding the workforce structure and movement, configuration of training schemes, and budget structures, through investigating some national industry-related bodies such as directorate of petroleum workforce and directorate of financial affairs at the National Oil Corporation (NOC). Figure 1.3 demonstrates the various parts of the research survey questionnaire.

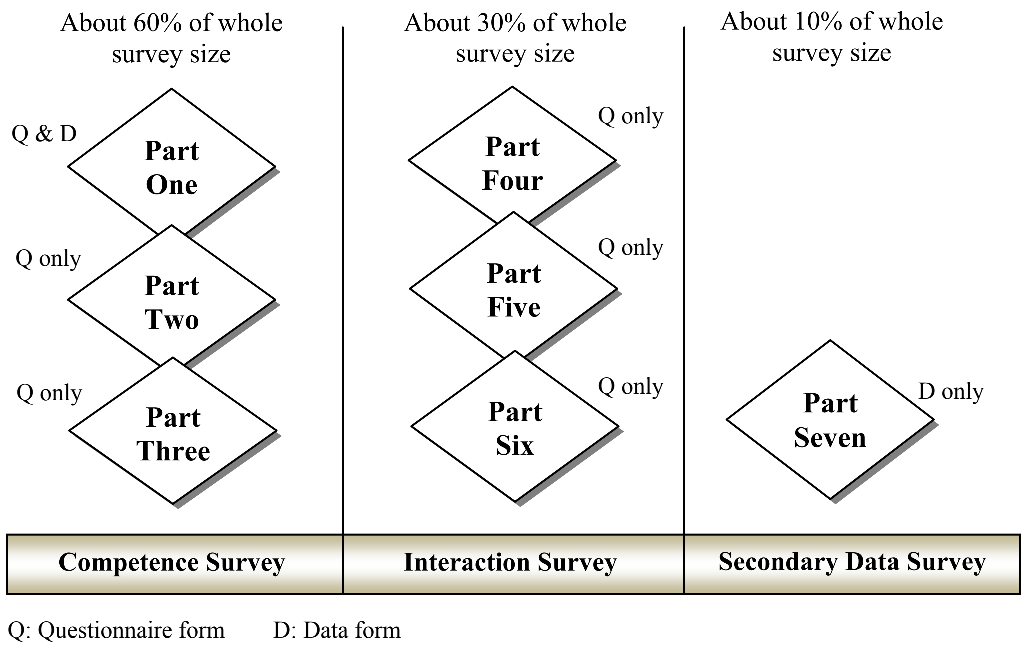


Figure (1.3): Main Parts of Research Survey Questionnaire

– *The Synthesizing Process of Postulate Management Framework*: The postulate Management Framework for Technology Development (MFTD) is in fact the research overall outcome. It is in essence a combination of some vital ingredients, namely: 1) The survey potential findings which lead to identifying strengths and weaknesses of the technological competence of Libyan oil industry. 2) Output of literature review. 3) The commonalities of technology strategy/policy frameworks used in some particular countries.

Furthermore, the postulate MFTD is an explanatory framework designed essentially on activity-based approach which comprises three interrelated types of management activities, namely: 1) *Planning activities* such as technology strategy formulation. 2) *Action activities* such as capacity building, knowledge generation, driving innovation business, etc. 3) *Controlling activities* such as monitoring of innovation performance. At last, the framework should answer questions of managing the implications of successful technology development in Libyan oil industry or in any similar sector of developing country. Figure 1.4 shows the synthesizing process of the postulate framework.

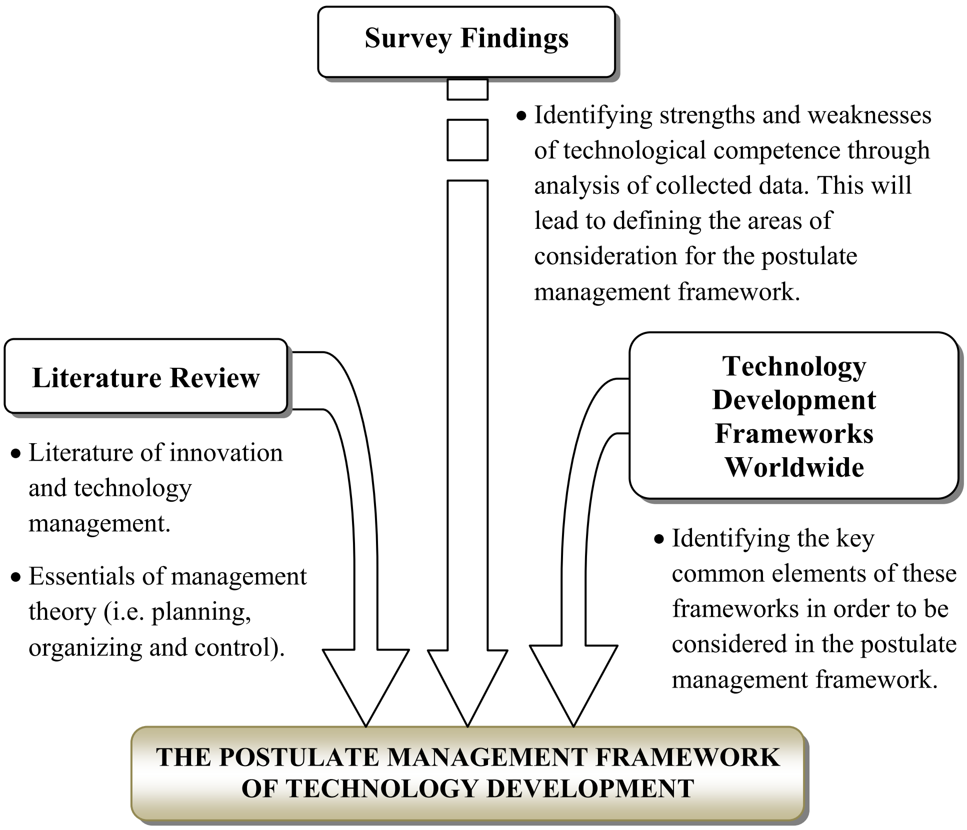


Figure (1.4): The Synthesizing Process of Postulate Management Framework

1.6 LIMITATIONS AND DELIMITATIONS OF STUDY

– Measuring the variables of technological competence in many aspects (e.g., scientific and technical output, degree of technology assimilation, dependency on foreign supplier, etc.) is limited in this study to using the qualitative scales only (e.g., good, low, regular, rare, strongly agree, in-house, foreign, etc.). This results consequently in relative finding indications, which dependent largely on the respondent appraisal to the variable being measured, due to lack of clear-cut and accepted set of references for comparison. Therefore, to circumvent such disparate evaluation in some future work one should rather use quantitative measurements, which are not available for this study, and benchmark the results accordingly to the competence variables in some other peer industries of particular countries.

– The part five of the questionnaire, which is dedicated to survey the interactions of national universities & research institutes of public ownership with Libyan oil industry towards developing petroleum technology, is limited to explore the universities which: 1) Comprise principally departments of earth science, petroleum engineering, chemical engineering and chemical science as that will enhance the likelihood of having some technical interactions with Libyan oil industry. 2) Have been established relatively since a long time because that will increase the likelihood that these universities have experienced some technological petroleum achievements and have had accordingly some interactions with Libyan oil industry.

– The postulate management framework is limited to analyze the sectoral system of innovation under the effects of both national institutional set-up and international regulations, for instance, intellectual property rights.

– Global technological opportunities are practically unlimited and the contribution of the sectoral system under study to global knowledge is modest. Hence, the main focus in this respect is confined to how well the postulate management framework can help raising and activating the absorptive capacity building for technological catching-up, as the prime priority, rather than getting involved in the implications of developing novel technology from the outset (i.e., not for innovations in an immediate sense) for the sake of exploiting the potential global technological opportunities.

- Libya is considered a developing country. It is conventionally indicated that most of developing countries are facing and sharing, to a large extent, the same characteristics of barriers and difficulties of technological catching-up regardless of either at national or sectoral level (see Crane, 1977; Oyelaran-Oyeyinka and Lal, 2006; UNIDO, 2005; Global Competitiveness Index published frequently by United Nations). Therefore, what it is supposed to be suitable for Libya to catch up technology would be accordingly suitable, to a large extent, for most of developing countries.

- The sectoral system is dynamic in its nature (i.e., grows up and evolves over time). This becomes especially significant in this perspective since it is necessary to take explicitly into account that the management framework under consideration should be built and subject to continuous development based on that dynamic effect.

- Each actor in the sectoral system operates under constraints of limited resources (e.g., technological capabilities, information, fund, etc.) and can not, therefore, work in isolation of others. This becomes important, in view of the vast global set of technological opportunity, to emphasize the sense of partnership and interactions between the system's key players when designing the postulate management framework of interest.

Chapter Two

INNOVATION AND TECHNOLOGY MANAGEMENT: LITERATURE REVIEW

"When you always do what you have always done, you always get what you always got"

Socratic saying

2. INNOVATION AND TECHNOLOGY MANAGEMENT: LITERATURE REVIEW

2.1 INTRODUCTION

The originality of a research topic often depends upon critical review of a body of relevant literature. The nature of this concern throws oneself into the need to identify the key theories, concepts, ideas and methodologies developed earlier in relation to the research topic. Besides, the literature review will attempt to emphasize what are the main debates about the research problem that have been addressed to date? How the knowledge on the topic is structured and organized? How have approaches to these questions increased our understanding and knowledge? As well as to outline some of dimensions and elements which verify the worthiness of the research thesis.

Within this context, this chapter aims at revealing the literature review of the research topic. The scope of reviewing has been designed firstly to highlight the worthiness of the thesis, as being related to management of technology development, through demonstrating importance of knowledge creation in today knowledge-based economy, impact of the technological change on the economic growth, and technology gap between nations. Secondly, in order to promote the scientific contribution of the thesis the scope of literature review discloses some of key research gaps that relate to technology development issues in areas of innovation systems and interaction of technological absorptive capacity. Thirdly, a comparative study of some science and technology strategies for an arbitrary mix of some developed countries (i.e. UK, Japan, Canada, and Australia) and some developing countries (i.e. India, Malaysia, Indonesia and Iran) or in terms of oil-producing countries (i.e. Iran, UK, Canada, Australia, Malaysia, Japan) is taken place in order to determine the common essentials for the process of developing technology. Eventually, some concluded findings are established to sum up the results of all previous sections.

2.2 KNOWLEDGE-BASED ECONOMY

Throughout history, knowledge has been considered a significant element for improving the quality of mankind life. What have changed over time are the characteristics and the quality of knowledge, the relative importance of science as its source, the methods by which the knowledge created, stored, accessed, transmitted, acquired and retrieved, and its virtual importance as a production factor. In this sense, knowledge in terms of its dual aspects; codified knowledge and tacit knowledge (i.e., a knowledge embedded in people) are the key elements for a nation development, main drivers of growth, and major determinants of competitiveness in the global economy. Porter (1990) had already pointed out a decade ago that; a nation could no longer rely on abundant natural resources and cheaper labour, and that comparative advantage would increasingly be based on combinations of technical innovations and creative exploitation of knowledge (Gürüz and Pak, 2002). Besides, the United Nation (2005) in its millennium project concluded that; innovation and technology are principally needed to transform countries from reliance on the exploitation of natural resources to technological innovation as the basis for development.

Furthermore, the world society is entering into an era where the future will be essentially determined by people's ability to wisely use knowledge, a precious global resource that is embodiment of human intellectual capital, and technology. The "*knowledge-based economy*" places great importance on the diffusion and use of information and knowledge, as well as its creation. In this new economy, individuals and companies are obliged to focus on maintaining and enhancing their knowledge capital in order to innovate, and their ability to learn, adapt and change becomes a core competency for survival (Psarras, 2007).

The first step towards the broad use of the concept of knowledge-based economy was demonstrated in OECD (1995), it suggests;

> *"Economics has so far been unable to provide much understanding of the forces that drive long-term growth. At the heart of the old theory (neoclassical) is the production function, which says the output of the economy depends on the amount of production factors employed. It focuses on the traditional factors of labour, capital, materials and energy (...). The new growth theory; as developed by such economists as Romer, Grossman,*

Helpman and Lips; adds the knowledge base as another factor of production" (p.3).

In 1996, the OECD defined the knowledge-based economies as: ‘‘*Economies which are directly based on the production, distribution and use of knowledge and information*’’ *(p.3).*

The knowledge economy, especially with the associated growth of new information and communication technologies, means that there are increased demands for the ability to engage in formal reasoning and manipulating symbols. This implies a shift in the composition of skills with physical skills losing place to cognitive skills. As formal education tends to concentrate upon developing cognitive skills, rather than physical skills, new technologies tend to be associated with increasing demands for more highly qualified people. Formal education has become an increasingly important signal to employers that an employee has the cognitive ability to perform well in the work environment, whilst physical attributes are likely to decline in importance. However, cognitive abilities are not enough by themselves for a worker to work effectively. The ability to do a job depends upon an effective integration of a wide range of abilities which go beyond the immediate requirements of the technologies being used or the task in hand (Ducatel, 1998). For instance, in a recent synthesis of findings from Eurotecnet (1995), competencies required for work include: 1) Visualisation, i.e. the capacity to mentally manipulate models. 2) Understanding of a process - how machines function and the interaction between machines and the product. 3) Statistical deduction. 4) Verbal, oral and visual communication. 5) Individual responsibility for the product and the process. 6) The ability to make judgements. 7) The ability to combine business and technical issues.

This list comprises a mix of both cognitive and interpersonal abilities, which relate to a willingness to take responsibility, problem solving abilities, the ability to work with others and the willingness and capacity to learn. Importantly, several of the categories emphasise synthetic abilities where abstract cognitive abilities and inter-personal abilities come together (Ducatel, 1998).

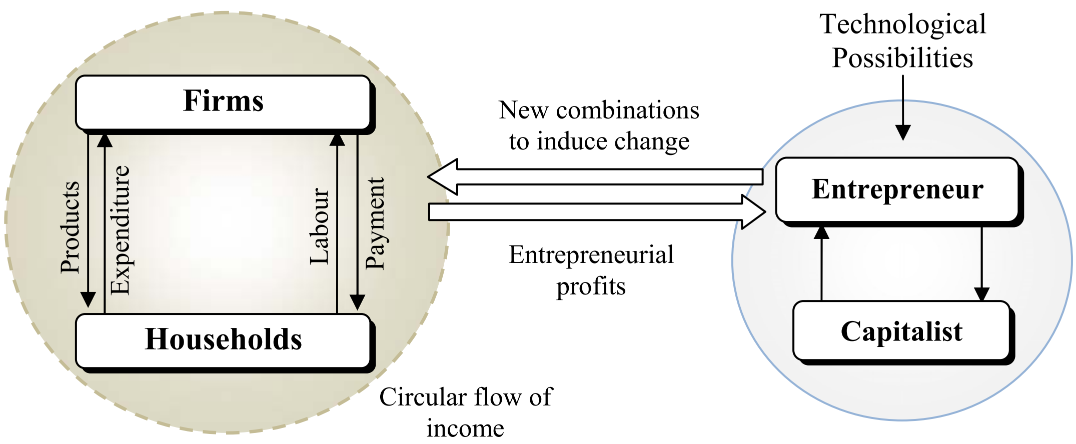
Moreover, the key source of sustainable competitive advantage within an industry in the knowledge-based economy is how a firm creates and shares knowledge for targeting profitability. To tackle such aim the knowledge management can be exploited to allocate resources to knowledge creation and diffusion for developing existing and new knowledge domains (Krogh et al., 2004). If knowledge management is to take hold rather than become merely a passing fad, it will have to be solidly linked to the creation of economic value and competitive advantage. This can be accomplished by grounding knowledge management within the context of business strategy. Given the state-of-the-art in knowledge management, firms just starting to build a knowledge management infrastructure are not far behind their more established rivals. By developing the proper strategic grounding, they will be able to focus and prioritize their investment in knowledge management and come out ahead of competitors who have not grounded their efforts in strategy (Zack, 1999).

2.3 TECHNOLOGICAL CHANGE AND ECONOMIC GROWTH

2.3.1 The Wealth Creation

The process of technological change has become an increasingly important area of study since the beginning of twentieth century when Joseph Schumpeter (1934) developed an original approach on the role of innovation in economic and social change; he defined innovation as "*new combination of existing resources*", and labelled this combinatory activity "*the Entrepreneurial Function*". In his early work, which is sometimes called "*Schumpeter Mark I*", he focused mostly on individual entrepreneurs. But in Later works so-called "*Schumpeter Mark II*", he also emphasized the importance of innovation in large firms (Fagerberg, 2005). With regard to the role of the entrepreneur in the overall process of economic development, Schumpeter described the entrepreneur as an active external agent of change, a generator of novelty "de novo", or as an active bearer of the mechanisms of change (Velde, 2004).

Figure 2.1 (p.22) demonstrates Schumpeter's model of economic development. The term circular flow of income refers to a simple economic model which describes the reciprocal circulation of income between producers and consumers. In the circular flow model, the inter-dependent entities of producer and consumer are referred to as "*firms*" and "*households*" respectively and provide each other with factors in order to facilitate the flow of income. Firms provide consumers with goods and services in exchange for consumer expenditure and "*Factors of Production*" from households. The circle of money flowing through the economy is as follows: total income is spent (with the exception of "*leakages*" such as consumer saving), while that expenditure allows the sale of goods and services, which in turn allows the payment of income such as wages and salaries. Expenditure based on borrowings and existing wealth – i.e., "*injections*" such as fixed investment – can add to total spending. In steady state, leakages equal injections and the circular flow stays the same size. If injections exceed leakages, the circular flow grows (i.e., there is economic prosperity), while if they are less than leakages, the circular flow shrinks (i.e., there is a recession). A much more interesting observations that in such a steady state all behaviour from actors in the model, be producers or consumers, is based on merely routines. The sellers of all commodities appear again as buyers in sufficient measure to acquire those goods that will maintain their consumption and their productive equipment in the next economic period at the level so far attained, and vice versa. On the other hand, the pair of entrepreneur and the capitalist is always looking for ways to induce change in the peaceful yet boring routine-life of the circular flow based on consumers' wants. The basic driving force behind structural economic growth is the introduction of new combinations of materials and forces, not the creation of new possibilities (Velde, 2004).



Source: Adapted from Velde (2004)

Figure (2.1): Schumpeter's Model of Economic Development

Schumpeter (1939) highlighted the tendency of innovations to cluster in certain industries and time periods, and the possible contribution of such clustering to the formation of business cycles and long waves in the world economy. Furthermore, he emphasized that; the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, and the new forces in industrial organization that capitalist enterprise creates (Schumpeter, 1943). Such potential to create new products, processes, markets are path-dependent in the sense that there are certain nations and locations which seems to have acquired that capability over time, for innovation process relies on the accumulation and development of a wide variety of relevant knowledge (Dicken, 1998).

Two major approaches emerged during the 1980s and 1990s as the dominant approaches to the analysis of the relationship between technology and growth. These are "*the Neoclassical Approach*", which is also dominant in other fields of economics, and "*the Neo-Schumpeterian or Evolutionary Approach*". Both of theses approaches agree on basic issue such as the importance of innovation and technology for economic growth, as well as the positive role that can be played by government policy for science and technology (Verspagen, 2005).

Besides, it is widely acknowledge that technological change and innovation are the major drivers for the economic growth. Innovation stimulates growth and economic transformation is highly dominated the economic growth body of literature (Denison, 1966; Cornwall, 1977; Crafts, 1985; Chenery et al., 1986; Conlisk, 1989; Grossman and Helpman, 1991; Barro, 1991; Aghion and Howitt, 1992; Boskin and Lau, 1992; Heertje, 1994; Freeman and Soete, 1997). The U.S. National Science and Technology Council (1996) mentions that, technical progress is the single most important determining factor in the nation sustained economic growth. As much as half the nation's long-term economic growth over the past fifty years was credited to technology (Khalil, 2000).

Boskin and Lau (1992) indicate that the three principle sources of nations' economic growth are enhanced capital, labour, and technical progress or equivalently "*Total*

Factor Productivity". In their study of economic growth in the United States, France, West Germany, Japan, and the United Kingdom, they show that;

> *"Over the period under study, technical progress is by far the most important source of economic growth, accounting for half or more (three quarters for the European countries), and capital is the second most important source of economic growth (except for the U.S.). Capital and technical progress accounted for more than 95 percent of the economic growth of France, West Germany, Japan, and the United Kingdom. In the U.S. where labour grew more rapidly than in other countries during this period they still account for 70 percent of economic growth" (Khalil, 2000, p.23).*

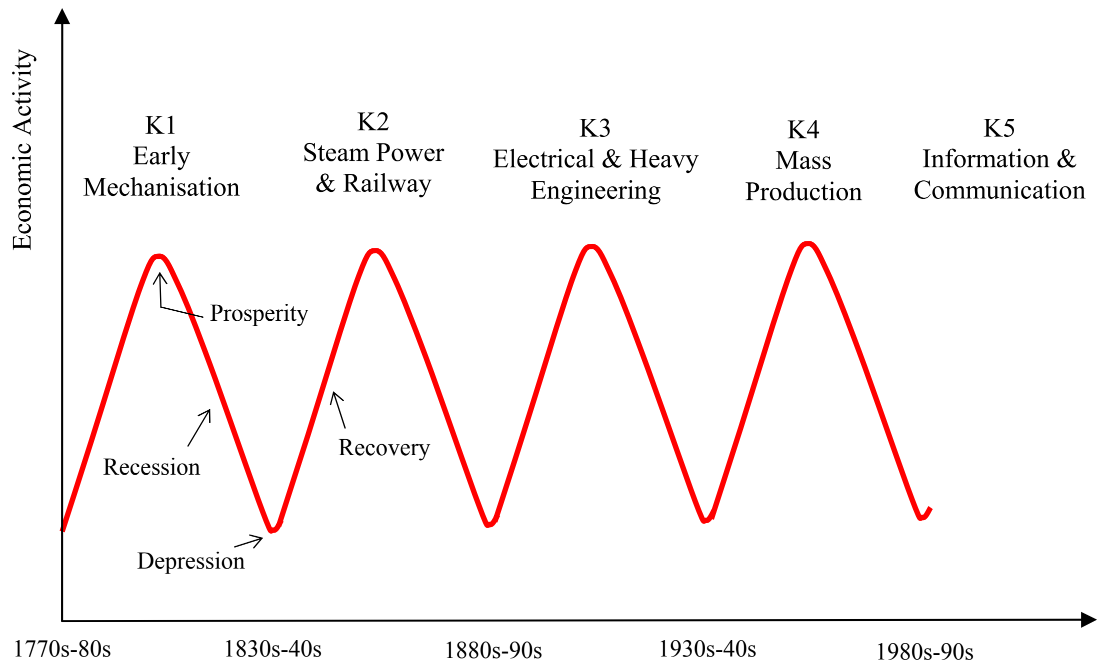
More recently, the OECD (1997) argue that, investment in knowledge, such as research and development, education and training, and innovative work approaches are key factors for economic growth. In addition, technological innovation has played a critical role in spurring growth in the industrial countries. But lessons derived from these experiences have not been applied in developing countries, where technological change remains a marginal part of national growth strategies. The goals offer an opportunity for the international community to plug this policy deficit. Despite the increasing globalization of technology, the involvement of developing countries in producing new technologies and innovations is almost negligible. The production of technological knowledge is concentrated in industrial countries. There are major differences in the generation of knowledge not only between developed and developing countries but also among developing countries. The challenge facing the global community is to create conditions that will enable developing countries to make full use of the global fund of knowledge to address development challenges (UN Millennium Project, 2005).

In "*How the West Grew Rich*", Rosenberg and Birdzell (1986) address two major issues of modern economics; 1) what explains the original onset of economic growth in the Western world; 2) why was this economic growth able to continue, without decline or stagnation, for several centuries and experiences sharp acceleration over time. They argue that the "*immediate sources of Western growth were innovations in* *trade, technology, and organization in combination with accumulation of more and more capital, labour, and applied natural resources*"*(p.20)*. Underlying this, however, was the importance of having "*the freedom of the economic sphere from political influence, as well as the role of the efficient government* in *contributing to the security of life and to advances in material welfare"(pp. viii, ix).* This autonomy of the economic sphere meant that individuals were free to organize new experiments, and to develop new products, technologies, and forms of organization towards permitting the economic system to operate effectively over the long run, and that's not only led to the original generation of Western growth but also to the Western ability to have growth continue and accelerate, unlike the paths taken by those other societies that may achieved, for their times and for limited time periods, relatively high income levels but were unable to continue their advance or to avoid eventual decline (Engerman, 1994).

2.3.2 Long Waves of Economic Cycle

As far back as 1930, the Soviet economist Nicolai Kondratieff studied the pattern of long-term economic development in the English economy and he observed that fluctuations occurred in Western economies every thirty years and attributed to the long-wave effect (see figure 2.2, p.26). In an age characterized by fast-paced technological change, the long wave, as argued here, is likely to be much shorter (Khalil, 2000). Moreover, Kondratieff argued that the net result was increasing economic activity in England, not decreasing activity. Kondratieff asked the question: How was capitalism in England renewed periodically and expanding overall? Kondratieff's answer was: technology. He plotted a correlation between times of basic innovation to times of economic expansion. Overall, the capitalistic economics were expanding rather than contracting because of periodic innovations of new technologies (Betz, 2003). Mensch (1979) also studied the long wave phenomenon and suggested that basic new technology began the economic expansion in each long wave. Graham and Senge (1980) concurred with the view that inventions and innovations trigger economic long cycles. Betz (1987) suggested that the process behind a long wave is an interaction between new technology, business opportunities created by new technology, and an eventual overbuilding of capital after the technology ages. He suggested a sequence of some events for the long-wave process, namely: 1) Discoveries in science create a phenomenal base for technological innovation. 2) Radical and basic technological innovation creates new products. 3) These products create new markets and new industries. 4) The new industries continue to innovate in products and processes, expanding markets. 5) As the technology matures, many competitors enter internationally, eventually creating excess production capacity. 6) Excess capacity decreases profitability and increases business failures and employment. 7) Subsequent economic turmoil in financial markets may lead to depressions. 8) New science and new technology may provide the basis for new economic expansion.

Figure 2.2 shows Kondratieff waves of economic growth and their main features.



Source: Trott (2008)

Figure (2.2): Kondratieff Waves of Economic Growth

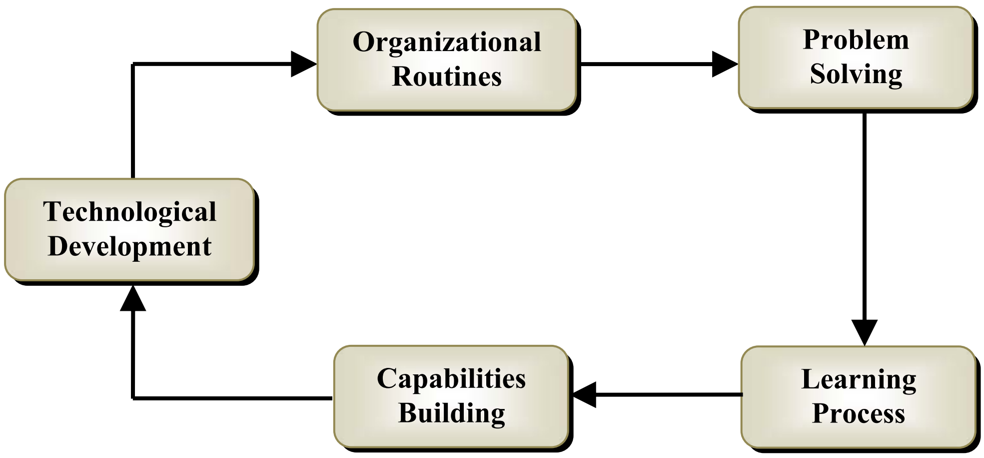
In their study of the emerging new growth phase of the fifth Kondratieff wave, Grübler and Nowotny (1990) argue that; since the early 1970s we are witnessing a volatile and turbulent transitional period towards a new phase of socio-economic development, in which the diffusion of a host of inter-related new technologies, institutions and forms of organization could lead to a renewed period of economic growth and prosperity. The beginning of such a diffusion phase, in which the ultimate characteristics of the future development trajectory are being shaped, could constitute an opportunity window for reducing disparities between countries as a result of their different degrees of economic development. In addition, they consider that, with reference to developing countries, the successful catching-up will depend more on an effective introduction and diffusion of the elements of the emerging new development regime than on a growth model along the trajectories and intensity levels of the previous model of economic development. In the next phase of economic expansion, criteria of system integration, flexibility and quality, environmental compatibility, value and information intensive (and relatively material and energy-extensive) products and a production system in which the whole philosophy of "*Just-in-Time*", high turn-round times and inventory minimization, unprecedented quality and precision levels, environmental compatibility, etc. will become dominant. Unlike in previous upswing, productivity increases will no longer be based on increasing economics of scale, but instead on increasing economics of scope.

The areas in which Grübler and Nowotny (1990) discuss the emerging new tendencies that shaping the next phase of economic development include the fields of energy (the focal point of interest in this section, manufacturing, transport and communication). The area of energy has, due to extreme price volatility since the beginning of the 1970s, been the focus of attention of analysts, policy-makers and the general public. In particular, the structural transition in the primary energy supply mix with the market dominance of petroleum (and the oil producers cartel OPEC) having reached its zenith of importance and starting to decline, if only in relative market share terms, and the apparent decoupling of energy from general economic growth, have been the most important characteristics of the 1970s and 1980s. These shorter-term developments have, however, somehow masked the perspective on the longer-term tendencies in the evolution of the energy system. In particular, it was historically never resource scarcity proper which led to the transition to new energy carriers, but better compatibility of new energy vectors with the social, economic and environmental requirements and boundary conditions of evolving societies. For instance, it was not the scarcity of wood fuel which led to the transition to coal starting in the 18th century, and it was not the lack of resources and supply sources which led to the transition away from coal to oil, after the middle of the 19th century. The driving forces were instead the higher quality, energy density and thus improved possibilities for transportation and storage, versatility and ease of use, as well as the emergence of new applications, which led to the transition to new forms of energy carriers. These driving forces become especially important under two main tendencies emerging from the energy debate. The first lies in the increasing globalization of environmental issues (climate changes) and the second trend deals with the future evolution of energy prices in general and that of oil in particular considering potential for further technology improvement and consequently cost reduction at all the energy chain from exploration, production to end use.

2.3.3 Cycle of Technological Change

Foster (1986) depicted the technological progression through a series of "*S-curves*" and that the technological change follows a cyclic pattern. He went on to suggest that any industry is accustomed to evolve through a succession of technology cycles. Each cycle begins with a "*Technological Discontinuity*". Discontinuities are breakthrough innovations that advance by an order of magnitude of the technological state-of-the-art which characterizes an industry. They are based on new technologies whose technical limits are inherently greater than those of the previous dominant technology, along economically relevant dimensions of merit. The nature of the technology cycle is dramatically affected by the cutting dimension of competence. Some discontinuous innovations are competence-destroying. Existing know-how become obsolete, and mastery of the old technology does not imply mastery of the new. Firms must embark on a new learning curve which is essentially unaffected by the firm's existing know-how, and technical professional require new training (Anderson and Tushman, 2004).

Based on the Schumpeterian approach, Nelson and Winter (1982) developed the "*Evolutionary Theory of Economic Change*". For them, the generation of new technologies is allowed by intra-organizational efforts undertaken by firms on the search for a competitive market position. Firms are exposed to a natural selection process, in which the survivors are those more technological innovative. The process of technological development is driven by organizational routines (i.e. a set of organizational abilities fundamental for the development of firm's core competencies). The productive activity represents a learning process undertaken by a routine. This routine is continuously challenged, as unpredictable problems come up requiring solution. The application of the found solution, in turn, represents a learning process, which allows capabilities development. This cycle never ends, characterising the central mechanism of the problem solving activity and of the improvement of routines and techniques. Figure 2.3 shows cycle of technological development



Source: Based on Nelson and Winter (1982)

Figure (2.3): Cycle of Technological Development

2.4 TECHNOLOGY GAP BETWEEN NATIONS

UNCTAD commission on science and technology for development (2006) defined the technology gap as "*the divergence between those who have access to technology and use it effectively, and those who do not*". In addition, such significant approach has been studied from the following perspectives: technology creation, diffusion, effective applications and domestic capabilities such as human skills and infrastructures, which would facilitate the creation, diffusion and the effective application.

In spite of technological achievements made by some developing countries in recent years, the technology gap between nations remains wide. For instance, one billion people do not have access to telephones and around 8 million villages or 30 per cent of all villages worldwide are still without any kind of connection. The gap exists not just in the creation and diffusion of technologies, but also in domestic abilities to put available technologies into effective use. Today high income countries spend around 1.5 to 3.8 percent of their GDP on R&D and fund more than 80 % of the world R&D activities. In contrast, most developing countries spend less than 0.5% of their GDP on R&D activities and some developing countries spend as low as 0.01% of their GDP. The gap is also evident in education; mean year schooling in 2003 was 12.1 years in the USA, 4.2 in Kenya and 0.8 in Guinea Bissau. Similarly, tertiary science enrolment ratio in 2003 was 27.3 per cent in Finland, 5.5 per cent in Colombia, 2.4 per cent in Albania and only 0.1 per cent in Chad (UNCTAD, 2006).

More detailed data also reveal substantially large national differences on domestic capacity building efforts. For example, tertiary enrolments as a percentage of relevant age group stands at almost 25 per cent for East Asia, 10 per cent for South Asia and Latin America, 7 per cent for Middle East and North Africa and 2 per cent for Sub-Saharan Africa (SSA). The tertiary enrolment ratio in 1999 was more than 50 per cent for Korea and Taiwan province of China, 30 per cent for Malaysia and Thailand, 13 per cent for China and 15 per cent for South Africa (a decline from 18 per cent in 1995). Of the five SSA countries studied (Zimbabwe, Kenya, Tanzania, Uganda and Ghana), the enrolment rate was less than 4 per cent. The sub-Saharan Africa countries have fallen behind in technological achievements as measured by "*manufacturing value added*" (MVA), production and manufactured exports. The performance for most sub-Saharan Africa countries, including South Africa, has either stagnated or worsened between the years 1980 and 2002, while East Asian countries have made substantial gains in MVAs and manufactured exports. More specifically, MVA per capita statistics indicate that among the countries studied, Zimbabwe had the largest base with a MVA production of more than $US 140 per capita in 1980, however, that number declined to $83 in 2002. The other countries had much smaller base, but their MVA performances, similar to Zimbabwe, had worsened between the years 1980 and 2002. South African MVA also declined from almost $600 to $450. Over the same time period, Malaysia's increased from slightly more than $300 to more than $1,200. China's MVA also increased to pass the level of $300 by 2002. Thus, regional comparisons show a big gain for East Asia over the years 1980 to 2002, and a small decline for SSA which had the smallest share of the global MVA to begin with (UNCTAD, 2006).

Technology achievement indices such as UNCTAD's *Innovation Capability Index* (ICI) measure the quantitative components of National Innovation Systems (NIS). Within this framework, SSA and North African countries have not made any significant gains in its innovative capacity between 1995 and 2001 and continued to have low index values among the regions.

Within the technology gap, special attention should be also devoted to the "*Digital Divide*" which is defined as; a growing asymmetry in the capacity of firms, institutions and individuals in different countries to use "*Information and Communication Technologies*" (ICTs) effectively in accessing and applying knowledge, and thus, spurring competitiveness and innovation. The digital divide between the information-rich and the information-poor countries remains significant at twice the average levels of income inequality and thus, is of increasing concern. In short, the technology gap between nations is wide. Some main findings have been concluded accordingly by UNCTAD (2006), namely:

– Technology gap exists between and within nations. It exists in all dimensions from accessing knowledge, to effective use of, and creation of knowledge.

– Technology creation, diffusion and effective use are not automatic processes and require carefully designed strategies and policies.

– Information and Communication Technologies (ICTs) emerge as a key sector in science and technology policies since the ICTs play a major role in accessing, processing and communicating knowledge and information.

– Many developing countries do not innovate at the frontier. For them, accessing, acquiring, locally adapting, effectively using and improving upon existing technologies are the main challenges.

– International technology transfers and international collaborative projects are important channels for developing countries to access to and acquire technologies developed in other countries. It is therefore recognized that stimulating these channels will be a right step in technological upgrading efforts.

– It is also recognized that local adaptation, effective use and improvement upon existing technologies require more than technology transfer. It requires domestic capacity building and raising human capital.

– Economic stability, government commitment and global economic considerations should be considered in designing science and technology policies.

– Raising human capital and skills through education and training are essential strategies in raising domestic capabilities. Special attention should be paid to encourage young people, especially women, to enter the fields of science and technology. Efforts should also be made to reverse the impact of brain-drain.

– Upgrading both physical and services infrastructure are important strategies for domestic capacity-building. A special emphasis is placed on services such as financial services, technical consulting, technology fore-sighting, incubators and public awareness units.

– Policies should be in place to encourage private sector’s active participation in R&D activities. Partnerships among the industry, university and the public R&D institutions should also be encouraged.

– International collaborative projects and partnerships should be encouraged with the aim of facilitating technology transfers to developing countries, addressing issues and problems unique to developing countries and developing human resource capacity in those countries.

As a result, nations' technological capabilities to acquire, adapt and develop upon scientific and technological knowledge are a major determinant of their capacities to narrow income and bridge technological gaps as well as to attain sustainable economic growth. Science and technology policies are vital elements among others to foster the creation and strengthening of those technological capabilities.

2.5 SYSTEMIC NATURE OF INNOVATION

2.5.1 National System of Innovation Framework

Concepts and Central Features:

Throughout the last fifty years, the theory of industrial innovation has moved from a very simple description of the entrepreneur and the isolated firms as innovating units to a more including set of elements. In other words, the development of innovation theory is one through which new elements of the firm's environment have been included in the theoretical system (Niosi et al, 1993). The firms do not normally innovate in isolation, but in collaboration and interdependence with other organizations. These organizations may be other firms (suppliers, customers, competitors, etc.) or non-firm entities such as universities, schools, and government ministries. The behaviour of organizations is also shaped by institutional set-up such as laws, rules, norms, and routines that constitute incentives and obstacles for innovation. These organizations and institutional set-up are components of systems for the creation and commercialization of knowledge. Innovations emerge in such systems of innovation (Edquist, 2005).

The idea of "*Innovation System*" can be tracked back to Frederich Liszt's conception of "*the National System of Political Economy*" (1841), which might just as well have been called "*the National System of Innovation*"(NSI). The analysis of national systems developed by Liszt took into account a wide set of national institutions including those engaged in education and training as well as infrastructure such as networks for transportation of people and commodities (Freeman, 1995). Liszt stressed the relevance of knowledge, the links between scientific institutions and productive sector and foreign technologies for economic development (Alcorta and Peres, 1998).

More recently, Freeman (1987) was first used explicitly the concept of national system of innovation to help describe and interpret the performance of Japan over the post-war period, he defined it as; *the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.*

Based on Liszt concept of "*national production systems*" and Hippel's work on informal technical collaboration among firms, Lundvall (1985, 1988) put the emphasis on user-producer interaction within the national economy. Technological flows and technology development interactions among firms appeared to him much more frequent within national boundaries than across borders. A study on technical alliances in the Canadian electronics industry conducted by Niosi and Bergeron (1992) supports Lundvall's analysis. This domestic interaction would basically explain the existence of national systems of innovation (Niosi et al., 1993).

The importance of the local supply of skills, specific local demands, and the pressure of competition for the national system of innovation have been stressed by Porter (1990).

Another definition was built around the concept by Niosi et al. (1993). They defined the national system of innovation as follows:

> *"A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders" (p.212).*

Furthermore, Niosi et al. (1993) considered that, at the very centre of any national system of innovation there is a network of institutions, the output of each being an input for other institutions within the system. In addition, they asked some relevant questions: Is the concept useful for other types of countries? Do NSIs exist in developing and socialist countries? Can the concept shed some light on the missing building blocks (or the missing links between blocks) within socialist and developing countries? They argued consequently that; the concept and theories that are the basis of a national system of innovation can be probably be applied with minor modifications to less developed market economies, and the whole set of concepts used in the description and explanation of Western national systems of innovation is probably less useful, and would need to be substantially redefined to be applied to non-market economies.

Nelson (1993) does not have one clear-cut definition of NSI, he defined it as; *a set of institutional actors that, together, plays the major role in influencing innovative* *performance*. He argues, sectors and technological systems, within a nation, have a powerful shaping influence on the structure and dynamics of a national innovation system, whilst national context have important influences on sectoral conditioning and performance. Thus, prior institutional endowments of a national system may help or hinder innovative activity and performance within particular sectors of a national economy.

Whilst, Patel and Pavitt (1994) defined the national system of innovation as follows:

> *"The national institutions, their incentives structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change-generating activities) in a country" (p.79).*

But this definition remains very broad and begs two major questions: 1) Which institutions, incentives and competencies are important for national systems of innovation? 2) What are the important differences amongst countries in the rate and direction of technological accumulation?

In answering these questions, Patel and Pavitt (1994) argue, four sets of institutions are widely recognized as central features of national systems of innovation in all countries: 1) Business firms, especially those investing in change-generating activities. 2) Universities and similar institutions, providing basic research and related training. 3) A mixture of public and private institutions, providing general education and vocational training. 4) Governments, financing and performing a variety of activities that both promote and regulate technical change.

Furthermore, for incentives, they mentioned that the economic case for government support for basic research is accepted in all countries. They added, it is now widely recognized that one major reason for observed international differences in growth and trade performance is the existence of international gaps: in other words, international differences in technological competence resulting from differences in the volume and sectoral pattern of R&D and related activities.

Thus, it can be claimed that a nation's system of innovation is the engine of growth for its entire economy, and one can accept that, there are some key drivers of innovation in contemporary innovation systems such as, knowledge flows, institutional set-up, economic competence and interactive learning.

In summary, there seems to be general agreement that the main components in systems of innovation are organizations (among which firms are often considered to be the most important ones) and institutions. However, the specific set-ups of organizations and institutions vary among systems (Edquist, 2005).

Innovation Analytical Framework:

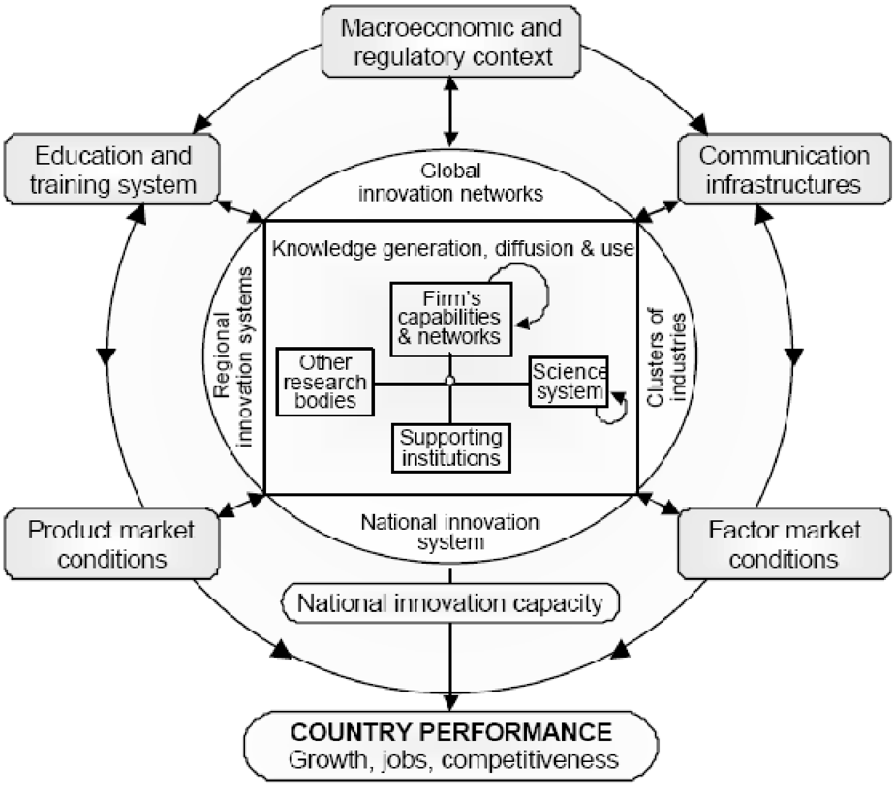
It is noteworthy that the concept of the NSI has gradually been spreading from the academic realm to the world of policy-makers. It increasingly used by international organizations as an analytical framework for the patterns and determinants of innovation processes within nations (see OECD, 1999, 2002b, 2005b). Edquist (1997a) has considered that; the NSI is not a formal theory but rather a conceptual framework for addressing the issues in question from a holistic, interdisciplinary and historical standpoint. He outlined some common characteristics of the systems of innovation approach such as: 1) Innovation and learning; 2) Their holistic and interdisciplinary nature; 3) The natural inclusion of a historical perspective; 4) Differences between systems and non-optimality; 5) Their emphasis on interdependence and non-linearity; 6) The incorporation of product technologies and organizational innovations; 7) The central role of institutions in the systems of innovation approach; 8) Their conceptually diffuse nature; and 9) The focus of the systems of innovation literature on conceptual constructs rather than on a more deeply rooted theoretical framework (Archibugi et al., 1999).

Balzat (2002) concludes that, a definition of national innovation system should contain and emphasize at least three crucial things: 1) The consideration of the entire innovative process; 2) The analysis of various main actors involved in these processes (plus the linkages between them); and 3) The institutional set-up serving as a framework for economic action.

According to the World Bank (2002), an NSI is a web of knowledge-producing organizations in the education and training system together with: 1) Appropriate macroeconomic and regulatory framework, including trade policies that affect technology diffusion. 2) Innovative firms and networks of enterprises. 3) Adequate communications infrastructures. 4) Other selected factors, such as access to the global knowledge base or certain market conditions that favour innovations.

As concluded in OECD (2002b), the performance of an innovation system increasingly depends on the intensity and effectiveness of the interactions between the main actors involved in the generation and diffusion of knowledge.

Figure 2.4 demonstrates actors and linkages in innovation system



Source: OECD (1999) as cited in Feinson (2003)

Figure (2.4): Actors and Linkages in Innovation System

System Activities:

The innovative activities of enterprises do not only depend upon intra-firm organizational capacities but are fundamentally shaped by the organisation's institutional environment as well as through specific technological or scientific patterns in which innovation processes are embedded. Thus, national or regional differences in technological performance can be attributed, at least to a significant extent, to variations in the institutional environment (Lundvall et al., 2002).

Edquist (2005) believes that it is important to study the activities (causes, determinants) in systems of innovation in a systematic manner. He added, the hypothetical list of activities presented below are not ranked to importance, but start with knowledge inputs to the innovation process, continues with the demand side factors, the provision of constituent of systems of innovation, and ends with support services for innovating firms. Besides, this list is provisional and will be subject to revision as our knowledge about determinants of innovation processes increases. The following activities can be expected to be important in most systems of innovation: 1) Provision of research and development (R&D), and creating new knowledge. 2) Competence building in the labour force to be used in innovation and R&D skills. 3) Formation of new product markets. 4) Articulation of quality requirements for new products. 5) Creating and changing organizations needed for the development of new fields of innovation. 6) Networking through markets and other mechanisms, including interactive learning between different organizations (potentially) involved in the innovation process. 7) Creating and changing institutional set-up. 8) Incubating activities, e.g. providing access to facilities, administrative support, etc. for new innovative efforts. 9) Financing of innovation processes and other activities that can facilitate commercialization of knowledge and its adoption. 10) Provision of consultancy services of relevance for innovation processes, e.g. technology transfer, commercial information, and legal advice.

In addition, Edquist (2005) argues; even if we knew all the determinants of innovation processes in detail (which we certainly do not now, and perhaps never will), we would not be able to control them and design or build systems of innovation on the basis of this knowledge. Centralized control over systems of innovation is impossible and innovation policy can only influence the spontaneous development of systems of innovation to a limited extent.

Moreover, research and development (R&D) partnership has been recognized as a principal mechanism by which actors strengthen interaction among themselves. Collaborative R&D especially enables firms to enlarge their available knowledge pool; and R&D co-funding enables firms to take on challenges in innovation they might not attempt otherwise. All such interactions, theoretically, should be helpful to firms, but in reality some may not be effective. As the innovation-system framework becomes widely accepted as the basic paradigm by which to understand capacity for innovation and as joint R&D gets more attention, the identification of just how effective such activities are becomes a compelling issue (Lee and Park, 2006).

Dynamics of Innovation Systems:

In the context of dynamics of innovation systems, OCED (2002b) assumes that innovation systems derive their dynamism from certain dimensions of growth that are typical for viable, purposeful systems, namely:

– *Interactions and linkages*: These are the key ingredients of the interactive model, and the NIS approach assumes that growth in interactions lead to improved innovation performance. In line with this discussion, not only the quantity of these interactions is important, but also their quality. Hence, innovation systems may grow through complementary interactions between innovators and their partners.

– *Growth in manpower and population*: This dimension points to the very basic item in human systems and how they repose on the population's general quality, including physical and general health. Hence, it is difficult to assume dynamic innovation systems without a minimum level or growth in the welfare of populations.

– *Economic growth* includes growth in disposable factors of production as well as the supply of skills and scientific and technical knowledge. From a systemic point of view, it may be stated that economic growth should exceed the growth of population and manpower for the system to remain viable.

– *Growth in the operational reserves of the system*: The environment may suddenly present new challenges, and both material and human resources need to be available for new uses. The existence of such slack resources defines to a great extent the degree of flexibility and responsiveness of innovation systems.

– *Growth in autonomy or the ability of systems to develop by self-determination*: The growth in autonomy contrasts with the often overstated notion of inter-dependence in innovation systems being a key feature. Such autonomy of innovation systems or their sub-systems is a key source of dynamism. On the one hand, autonomy rests on social cohesion or social capital to facilitate interactions, networking and communication. On the other hand, autonomy rests on the ability to act in correspondence with this learning.

– *Growth by transformation*: Innovation systems that are growing in various ways will sooner or later be victims of scale effects. Growing systems tend to become locked in or jammed by inefficient communication and interaction. Systems can therefore only grow in the wide sense of the term if they are regularly transformed through strategic simplifications. An illustrative example is the tendency for political systems to grow in administrative regulations that impede innovation, leading to the need for simplification of these regulations. Another example is growth through de-centralisation and broader use of e.g. regional innovation systems. The most important task for policy makers in the current innovation-driven economy could be to facilitate these strategic simplifications.

– *Growth in goal-changing abilities*: This includes the capacity for major re-arrangements of both purpose and structure, and for the development of radically new solutions. This ability for the innovation systems to re-invent themselves and develop novelty and creativity rests on advanced learning as well as autonomy, as mentioned previously.

Influence of Globalization:

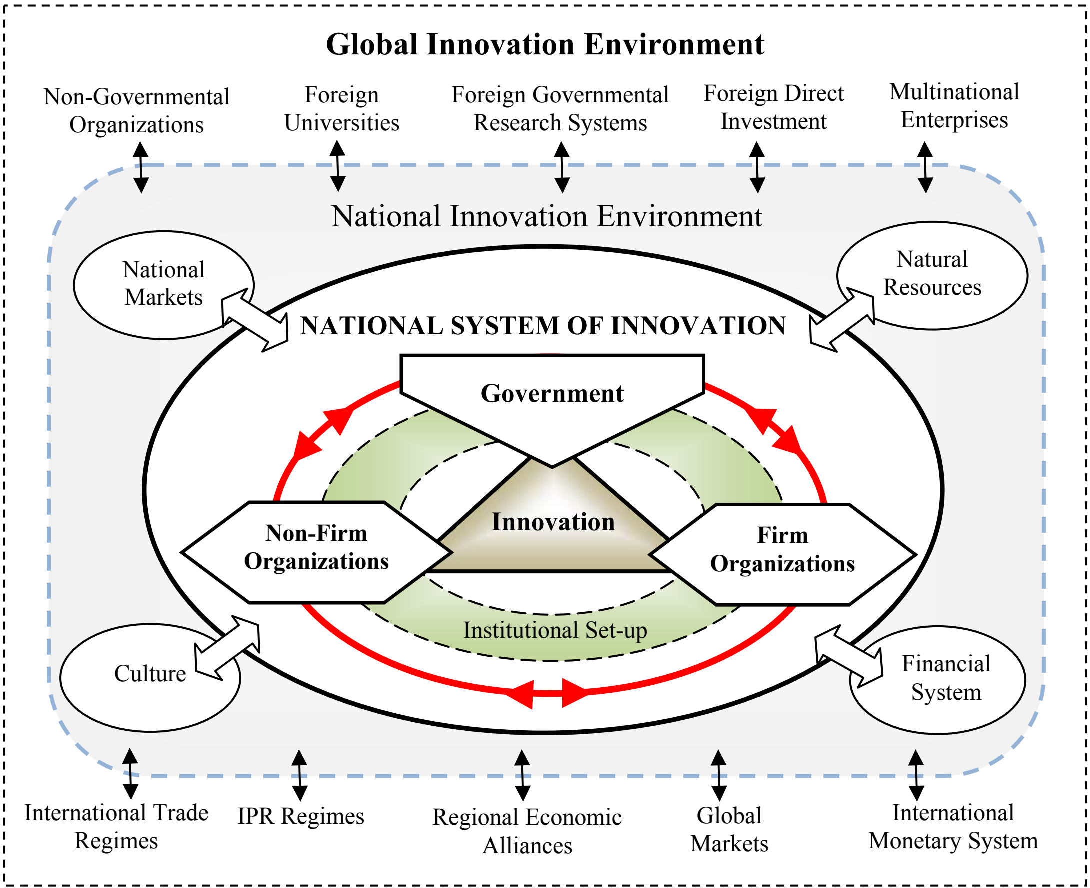
In his book "*The Borderless World* ", Ohmae (1990) argues that national frontiers are "*melting away*" in what he calls the "*Inter-linked Economy*" (ILE) - the triad of USA, European Countries and Japan, now being joined by New Industrialized Countries (NICs). This "ILE" is becoming so powerful that it has swallowed most consumers and corporations, made traditional national borders almost disappear, and pushed bureaucrats, politicians and the military towards the statues of declining industries (Freeman, 1995). As against this, Porter (1990) has argued that:

> *"Competitive advantage is created and sustained through a highly localized process. Differences in national economic structures, values, cultures, institutions and histories contribute profoundly to competitive success. The role of the home nations seems to be as strong as, or stronger than ever. While globalization of competition might appear to make the nation less*

important, instead it seems to make it more so. With fewer impediments to trade to shelter uncompetitive domestic firms and industries, the home nation takes on growing significance because it is the source of skills and technology that underpin competitive advantage" (p.19).

For most developing countries which characterized by institutional and organizational fragmentation, the task of setting the NSI in place calls for "*Capacity Building*" initiatives as a priority policy concern. Not much has been achieved yet in this respect, however, so that the potential benefits of technology globalization are likely to be unevenly distributed across the spectrum of countries. Thus, the newly industrializing countries are, by virtue of their economic status, more favourably placed than the low income developing countries to address the issue of innovation through the institution of the NSI. Policy in developing countries is also under the pressure of having to respond to the challenges of the global intellectual property rights (IPR) regime enacted by the World Trade Organization (WTO) and brought forth by the rapid pace of globalization. Globalization has not produced a level playing field for "*players*" in the innovation field in both developed and developing countries. Empirical evidence on R&D location shows that firms still prefer to establish strategic innovation activities in their home countries, despite globalization of investment in innovative activities. Cross-border R&D, however small, is taking place largely among the advanced countries, while newly industrializing countries (NICs) are also seeking to increase their respective shares of global R&D (Lakhwinder, 2004).

To understanding the context more broadly, figure 2.5 (p.42) demonstrates a simplified structure of the NSI concept. The structure begins with the narrow version of national system of innovation which encompasses the "*Triple Helix*" (university-industry-government), its interactions, and the institutional set-up essential to creating innovation. The second level is referred to as the national innovation environment, while a third level, the global innovation environment, represents the international arena in which national systems of innovation function. This level includes non-governmental organizations, foreign sources of scientific and technological research, multinational enterprises and foreign direct investment, intellectual property regimes, international trade regime, regional economic alliances, global markets such as product market and resource market, and international monetary system.



Source: Adapted from Feinson (2003, p.29)

Figure (2.5): Environment and Components of National Innovation System

Developing countries, however, seem to ignore the importance of national innovation systems, preferring instead to adhere to the intellectual property rights regime put in place by the WTO. The possible reason for this is twofold: 1) Developing countries appear to perceive, if naively, that because technological globalization has become pervasive, domestic agents of production will have no problem in drawing on the global pool of knowledge. The focus is thus on liberalization policies, the global knowledge market and its accessibility to developing countries. But this position assumed by developing countries smacks of the naive neoclassical view that innovation is an automatic and costless process. Nothing, however, can be further from the truth. Moreover, the WTO's strict IPR regime is generally criticized for being disposed in favour of the interests of enterprises in developed countries and against innovation and capability development initiatives in developing countries. 2) The apparent neglect of the active role of the state in promoting national innovation systems relates to the budgetary implications of structural adjustment policy. The pursuit of stringent control over fiscal deficit has the effect of reducing the capacity of governments in developing countries to allocate resources for the strengthening of national innovation systems. The fast pace of globalization has thus made intervention by the state rather difficult. It has not, however, diminished the importance of state intervention; rather it has heightened the case for capability development so that developing countries could maximize the benefits to be derived from the spill over effects of the global technology market (Lakhwinder, 2004).

For many, if not most developing countries, technological catching-up depends on the extent to which they are able to position their national innovation systems and environments to best take advantage of knowledge flows originating at the global level. In addition, Juma et al. (2001, p.638) note, "*many of the developing countries will have to move from natural resource extraction economies to knowledge-based ventures that add value to these resources. All these changes require a shift in public policy at the national and global level. Domestic innovation will not be possible without access to international markets; access to international markets will not be possible without domestic technological innovation. Local factors and global dynamics are thus intertwined in new ways requiring fresh approaches to domestic and international policy*". This perspective strongly implies that attention to single issues or sources of knowledge flows, such as patents or adoption of a mix of technology transfer strategies that is passive rather than active in nature, will not produce fundamental improvements in economic development (Feinson, 2003).

Hitherto, globalization has a dual dimension in the way the emergence of new technology producers (Athreye and Cantwell, 2007). First dimension related to global demand, where the rates of growth of exports and imports in the global economy provide or close a demand opportunity for all countries—this may be especially important in poorer countries where low incomes may cause domestic markets to be small to start with. Periods of relatively greater openness are therefore also often periods where the world economy enjoys a boom in demand as a result of growth in incomes of trading countries. This growth of demand may contain new technological opportunities in as much as technological opportunity is dependent both upon the novelty of product demand and a large scale of operations. In addition, in developing countries export demand provides access to a wider range of high income consumers that require higher quality products than may be broadly in demand at home (Pasinetti, 1981). Globalisation in this first sense provides the preconditions for the generation of technology within developing countries through the measure of the openness of the world economy to trade. The demand-pull approach to innovation (see Schmookler, 1966; Vernon, 1966) stresses this connection between the growth of demand and the rise of innovation, even if it was originally applied in a more localised domestic setting in considering this impact of demand. The second dimension of globalisation (and the more widely studied one) is the ability of countries to exploit such demand booms. Here supply side factors such as levels of infrastructure, stocks of human capital and existing technological capacity condition the influence of openness. Whilst openness allows opportunities to import capital goods and technology-embodied products, the presence of local human capital, and linkages to demanding users such as foreign-owned firms may well play an important role in the exploitation of the opportunities offered by openness, while the capacity to exploit these advantages may also vary with dynamic local firm capabilities and the institutional infrastructure of the country (Fagerberg, 1994; Verspagen, 1991). This second dimension is thus quite distinct from the first dimension, but it is reflected in the geographical dispersion by multinational companies (MNCs) of their subsidiary sources of technological knowledge creation (Cantwell and Mudambi, 2005).

2.5.2 Innovation System for Development Framework

Concepts and Applicable Nature:

The concept of the national system of innovation, hence, has been attaining attractiveness as a core conceptual framework for analysing technological change, which is considered to be an essential basis for the long-standing economic growth of a nation. Most of scholars from different academic disciplines concentrate, to a large extent, on analyzing the NSI in developed countries, but only a few studies focus on the NSI in developing countries. The argument here is based on the understanding that the specific nature of the NSI and its related issues in developing countries, which are less successful in terms of technological catching-up are different from the developed counterparts (Intarakumnerd et al. 2002). Worth mentioning that, the role of the innovation systems in developing economies is not the same as it is in developed economies. NSI in developed countries dedicated to maintain or improve an already established level of competitiveness and growth, whereas in developing countries the NSI has the task of catching-up (Feinson, 2003). Therefore, it is expected that the application of the NSI concept in developing countries would not be the same as it is in developed countries.

Dahlman and Nelson (1995) used empirical data such as; science and technology workforce, R&D intensity and educational figures, to analyze the interaction among social absorptive capability, NSI and economic performance by measuring and comparing fourteen developing countries' technological capability. They concluded that, the most vital element of any successful development strategy is the development of human resources.

Charles Edquist (2001) introduced the concept of *Systems of Innovation for Development* (SID), which is a different NSI approach to the one used in developed nations. The author emphasizes four main areas where SID differs from NSI: 1) Product innovations are more important than process innovations because of the effect on the product structure, 2) Incremental innovations are more important and attainable than radical ones, 3) Technological absorptions are more important than development of innovations that are new to the world, and 4) Innovations in low and medium technology sectors are more attainable than those in high technology systems.

Distinctive Characteristics:

More conceptual studies on NSI in developing countries have been made by Arocena and Sutz (2002) and Gu (1999). Both studies have shared the views that the NSI concept for developing countries is "*Ex-ante*", which is opposed to an "*Ex-post*" concept suitable for developed countries. This is for the reason that the innovative strengths at the micro- level that exist in developing countries remain isolated and many institutional set-ups that smooth the progress of innovativeness do not exist.

Gu (1999) as cited in Intarakumnerd et al. (2002, p.1446), articulated further that, NSI in developing countries has the following distinctive characteristics:

– NSI in developing countries is less developed by order. Historically, the technological and institutional properties necessary for modern growth were not developed within their systems. NSI in developing countries should be studied in the context of economic development, i.e. it is important to ask how did innovation related activities start, and how they continued to improve once started in relation to their local conditions and changing internal and external environment.

– NSI in a developing country is specifically related to the country's development level, i.e. the level of NSI development is quite connected to the level of country's economic structural and institutional development,

– Studies on NSI in developing countries should pay high attention to purposeful strategic management for catching-up,

– As market mechanisms in developing countries are still under-developed, the role of the market in developing countries in terms of promoting learning needs to be perceived differently from that of developed countries, and

– The main contribution to technical progress in developing countries, unlike developed countries, is capital accumulation rather than intangible assets such as knowledge and learning.

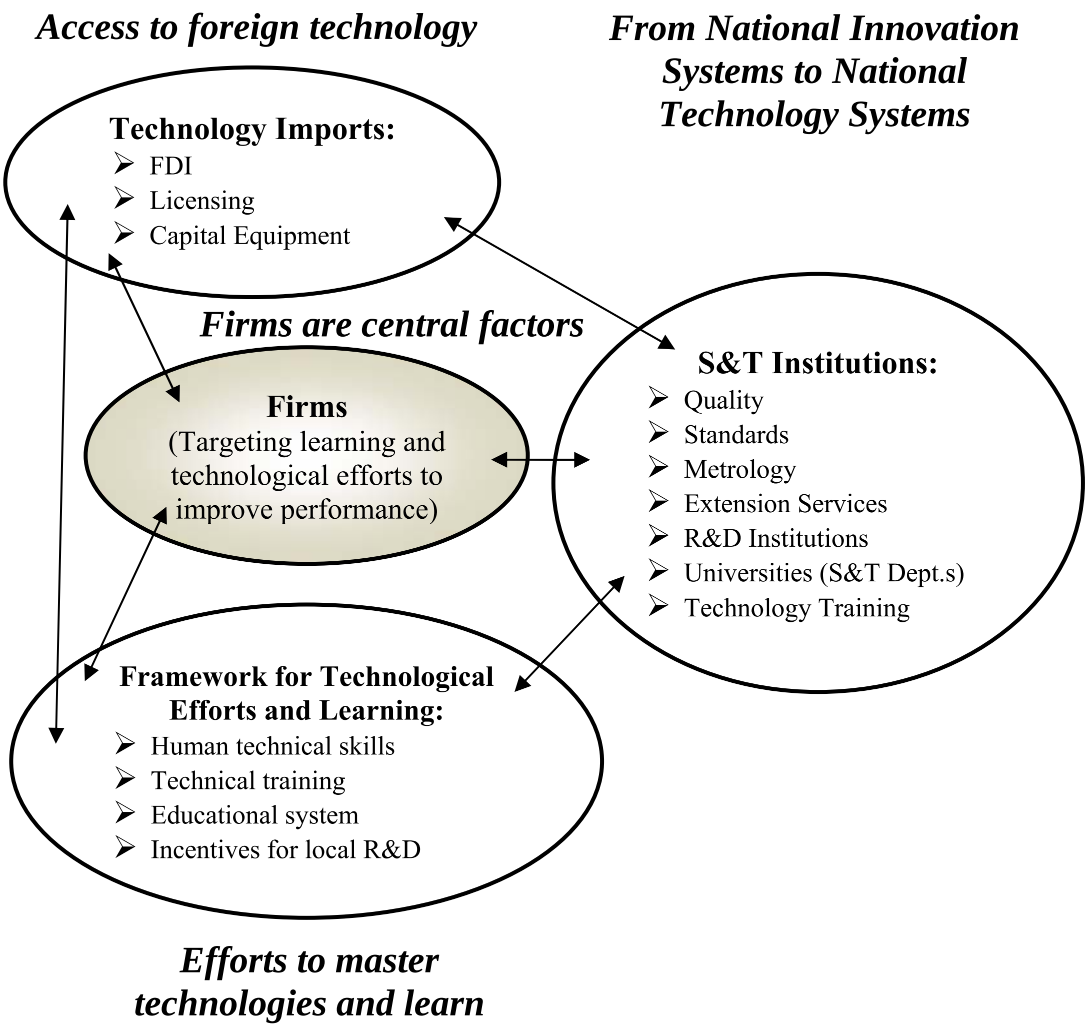
The participants in the ninth session of UNCTAD commission on science and technology for development (2006) recalled some of the common problems of the NIS in many developing countries, namely: 1) A lack of a clearly defined set of objectives for the development of science and technology and innovation; 2) The absence of the integration of S&T in the country's development policy objectives; 3) Lack of networks of S&T institutions (such as universities, research institutes, standards institutions); 4) Isolation of the preceding from the productive sectors of the economy; 5) Insufficient horizontal coordination between the main areas of public policy (fiscal and monetary, foreign investment, intellectual property, competition, trade, agricultural and industrial development, environment, health, etc.) that may be interrelated with investment in S&T development; 6) Insufficient vertical coordination between S&T policies at the national, regional and community levels; and 7) Lack of consultation with, and participation of all main actors (government agencies, business, academia, S&T institutions, consumers, labour and civic groups) in the formulation and implementation of S&T and innovation policies.

Intarakumnerd et al. (2002) conclude that developing countries are not "identical animals". The study of NSI in developing countries might have to differentiate between more successful intensive technological learning countries like "*New Industrialized Economies*"(NIEs) and the countries less successful in technological catching-up such as Thailand and other countries in Asia, Latin America and Africa. Basically characteristics of NSI in these countries are different from those of developed countries and NIEs in the several ways and one might need to study these countries from a different perspective. Furthermore, unlike Gu's argument (see Gu, 1999), development level of NSI in a country like Thailand does not link to its economic structural development level. As Thailand has experienced structural change from an agriculture-dominated economy to an economy predominantly oriented on industry and service both in terms of production and export, its NSI does not developed satisfactorily, i.e., it remains weak and fragmented.

In opposition to Gu's proposition (see Gu, 1999), studies of NSI in countries less successful in technological catching-up should focus not only on how innovation related activities start and improve over time but also, and more importantly, on factors that contributing to stagnancy and factors contributing to the long-running perpetuation of weak and fragmented NSI system (Intarakumnerd et al. 2002).

Arocena and Sutz (2002) indicated further that, industrial innovation in developing countries is highly informal (i.e. no determinant role for R&D activities in developing industrial products), and the dominant culture of these countries undervalues scientific knowledge and technological innovation.

Since many developing countries' systems are focused on effective usage and improvement of existing technologies rather than innovating at the frontier, Carlo Pietrobelli (2006) called for greater attention to the "*National Technology System*", which places greater emphasis on policies and measures that facilitate access to foreign technologies, and support domestic efforts, especially at the firm level, to master technologies and learn. Figure 2.6 illustrates some of the most important elements of national technology system.



Source: Pietrobelli (2006)

Figure (2.6): Framework of National Technology System

2.5.3 Sectoral System of Innovation Framework

Conceptual Definition:

The notion of "*Sectoral System of Innovation*" (SSI) appeared lately as a complement to some other concepts of systems of innovation such as national systems of innovation (NSI), which focus on national boundaries and non-firm organizations and institutions (Freeman, 1987; Lundvall, 1992; Nelson, 1993), regional/local innovation systems, in which the focus is on the region (Cooke et al., 1998), and technological systems, in which the focus is mainly on networks of agents for the generation, diffusion and utilization of specific technologies (Carlsson and Stankiewitz, 1991; Hughes, 1984; Callon, 1992).

A workable definition of a sectoral system of innovation and production has been developed by Malerba (2002, 2004), which states;

> *"A sectoral system of innovation and production is composed of a set of new and established products for specific uses, and a set of agents carrying out activities and markets and non-markets interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and (existing and potential) demand. The agents comprising the sectoral system are organizations and individuals (e.g. consumers, entrepreneurs or scientists). Organizations may be firms (e.g. users, producers and suppliers) and non-firm organizations (e.g. universities, financial institutions, government agencies, trade unions, or technical associations), including subunits of large organizations (e.g. R&D or production departments) and groups of organizations (e.g. industry association). Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviours. They interact through processes of communication, exchange, cooperation, competition and command, and their interactions are shaped by institutions (rules and regulations). Over time, existing sectoral systems undergo processes of change and transformation through the co-evolution of their various elements, and new sectoral systems may emerge" (Malerba, 2004, p.16).*

Carlsson et al. (2002) argue that rather than focusing on interdependence within clusters of industries, sectoral innovation systems are based on the idea that different sectors or industries operate under different technological regimes which are characterized by particular combinations of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and characteristics of the relevant knowledge base. These regimes may change over time, making the analysis inherently dynamic, focusing on the competitive relationships among firms by explicitly considering the role of the selection environment.

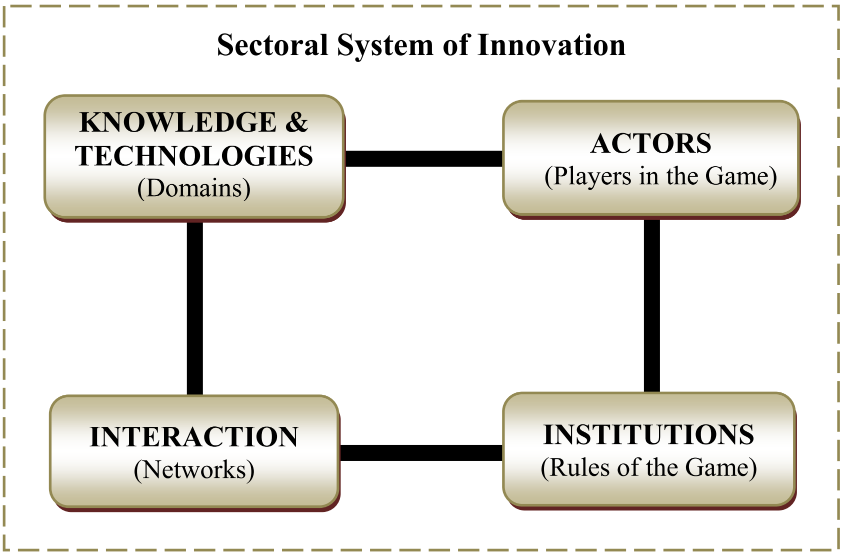
Structure of Building Blocks:

Based on previous definition, Malerba (2004, 2005) identified the main building blocks of a sectoral system of innovation (see figure 2.7, p.51), namely:

– *Knowledge and technological domain*: Any sector may be characterized by a specific knowledge base which plays a central role in innovation, technologies and inputs. In a dynamic way, the focus on knowledge and technological domain also places at the centre of analysis the issue of sectoral boundaries, which are usually not fixed but change over time.

– *Actors and networks*: A sector is composed of heterogeneous agents that are organizations or individuals. Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviours, which interact through processes of communication, exchange, cooperation, competition and command. Within sectoral systems, heterogeneous agents are connected in various ways through market and non-market relationships. Thus in a sectoral system perspective, innovation and production are regarded as processes that involve systematic interaction among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialization. Interaction includes market and non-market relations that are broader than the market for technological licensing and knowledge, inter-firm alliances, and formal networks of firms. Often their outcome is not adequately captured by our existing systems of measuring economic output.

– *Institutions*: Cognition, actions and interactions of agents are shaped by institutions, which include norms, routines, common habits, established practices, rules, laws, standard, and so on. They may range from those that bind or impose enforcements on agents to those that are created by the interaction among agents such as contracts; from more binding to less binding; from formal to informal such as patent laws or specific regulations versus traditions and conventions. Many institutions are national such as the patent system, while others are specific to sectoral systems such as sectoral labour markets or sector-specific financial institutions.



Source: Based on Malerba (2002, 2004, 2005)

Figure (2.7): Building Blocks of Sectoral System of Innovation

Differences in Systems of Innovation:

In this sense, one may ask, *what are the main differences between a sectoral system of innovation and a national system of innovation approach*? Malerba (2005) answers that, while national innovation systems take innovation systems as delimited more or less clearly by national boundaries, a sectoral system approach would claim that sectoral systems may have local, national, and/or global dimensions. Often these three different dimensions coexist in a sector. In addition, national systems of innovation result from the different composition of sectors, some of which are so important that they drive the growth of the national economy. Thus understanding the key driving sectors of an economy with their specificities greatly helps in understanding national growth and national patterns of innovative activities (Malerba, 2005).

To support the preceding discussion, we can take the case of the oil industry sector, where the multinational oil corporations may be active in a specific sector, but span their activities over different region and countries. They play, therefore, a major role in shaping the global dimension of that specific sector in parallel to its national/local dimensions.

Figure 2.8 demonstrates multiple dimensions of sectoral system of innovation.

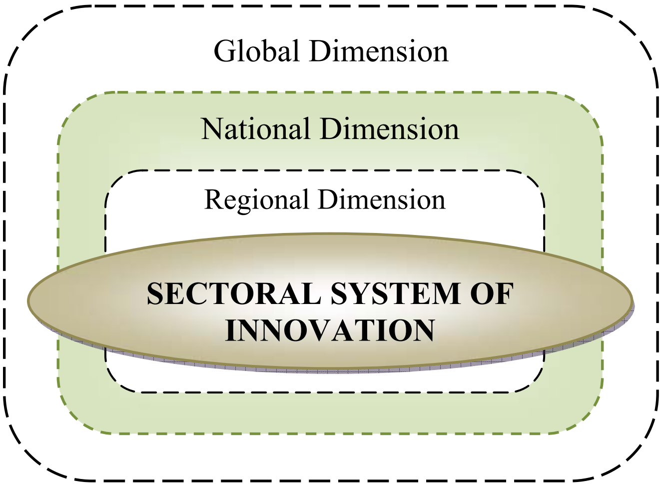


Figure (2.8): Multiple Dimensions of Sectoral System of Innovation

Over the last decade there have been several new concepts emphasizing the systemic characteristics of innovation such as sectoral systems of innovation and regional systems of innovation, but with focus on other levels of economy than the nation state. As a result, it has been argue that many, if not most, interesting interactions in the context of modern innovation tend to cross national border and that there is no a priori reason why the national level should be taken as a given for the analysis (Sharif and Chan, 2004).

Useful Analysis Tool:

Sectoral systems may be proven a useful tool in various respects: for a descriptive analysis of sectors, for a full understanding of their working, dynamics and transformation, for the identification of the factors affecting the performance and competitiveness of firms and countries and finally for the development of new public policy proposals. In a sectoral system, there are different levels for the analysis of agents: the individual, firm's sub-units, groups of firms and non-firms organizations. Flexibility has to be used in the choices of the unit of analysis, the variables to be examined and the fine grained analysis that has to be conducted (Malerba, 2002).

Sectoral Patterns of Innovation:

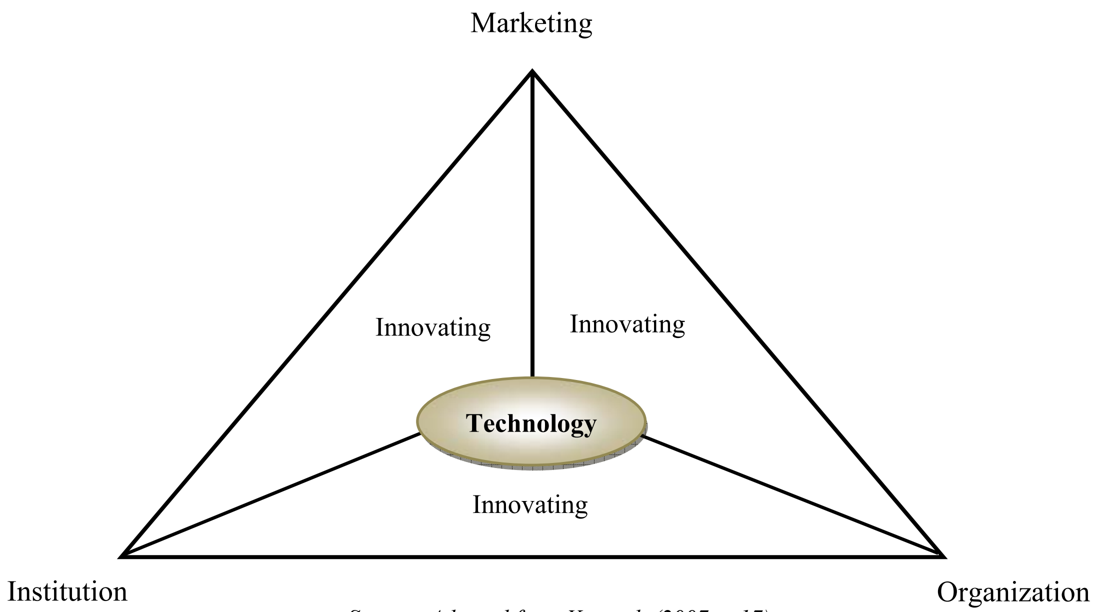
Innovation and technological change are highly affected by sector in which they take place. The agents, the relationships among actors and the institutions of a sector all exert a major and profound influence on the differences in innovation across sectors. Pavitt (1984) proposes four types of sectoral pattern for innovative activities: 1) In supplier-dominated sectors (e.g. textile, services), new technologies are embodied in new components and equipments, and the diffusion of new technologies and learning takes place through learning-by-doing and by-using. 2) In scale-intensive sectors (e.g. autos, steel), process innovation is relevant and the source of innovation are both internal (R&D and learning-by-doing) and external (equipment producers), while "*Appropriability*" is obtained through secrecy and patents. 3) In specialized suppliers (e.g. equipment producers), innovation is focused on performance improvement, reliability, and customization, with the sources of innovation being both internal (tacit knowledge and experience of skilled technicians) and external (user-producer interactions); appropriability comes mainly from the localized and interactive nature of knowledge. 4) Science-based sectors (e.g. pharmaceuticals, electronics) are characterised by a high rate of products and process innovations, through internal R&D and by scientific research done at universities and public research laboratories; science is a source of innovation, and appropriability means are of various types, ranging from patents, to lead-times and learning curves, also to secrecy. The Pavitt's taxonomy has been tremendously successful in empirical research and has guided the identification of firms and country advantages (Malerba, 2005).

2.5.4 Total Innovation Management System

In the 21st century, innovation theories are developed toward a higher level, and many scholars are conducting innovation theoretical research based on their understanding to the facts. The focus of the next research phase is the *"Total Innovation Management*" (TIM), defined as "*innovation by anyone at any time in all processes, among different functions and around the world*" (Xu et al., 2007). Researchers increasingly emphasize the idea of inspiring each employee's creativity and making everyone an innovator (Shapiro, 2001; Wheatley, 2001; Tucker, 2002).

Bean and Radford (2001) pointed out that innovation should be considered a business and that innovation should take place in every aspect. Some scholars think that the emergence of new organization forms such as outsourcing and strategic alliance have advanced the globalization of R&D, manufacture, and marketing (Chen, 2002), as cited in Xu et al. (2007, p.13).

TIM relates to innovation in all organizational sectors, all employees and covers all time and space dimensions. The all-elements innovation, as depicted in figure 2.9, can be creating synergy between the technological (mainly product, process, and portfolio) and non-technological (mainly market, organization, and institution) areas in an organization through effective tools and facilitating mechanisms that encourage and regulate innovation by every employee (Xu et al., 2007).



Source: Adapted from Xu et al. (2007, p.17)

Figure (2.9): All-Elements Innovation of TIM

2.6 TECHNOLOGICAL ABSORPATIVE CAPACITY

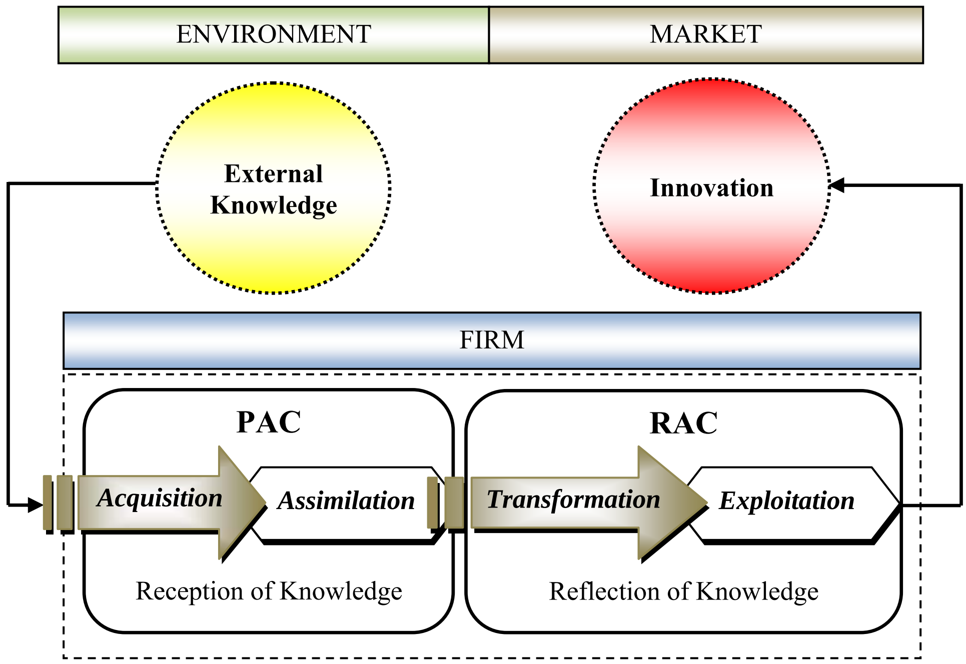
2.6.1 Conceptual Definition

In today global competition which for the most part is knowledge-based activities, the significance of knowledge acquisition, generation and exploitation along with developing learning capabilities are at the paramount concerns to all organizations producing technology. Firms strive to learn and generate knowledge faster than their competitors to gain the sustainable competitive advantage necessary for their survival. In addition, recent development in the management literature introduced the concept of firm's *absorptive capacity* as a crucial dynamic capability in knowledge-based competition (Zahra and George, 2002), and emphasized that firms endowed with greater absorptive capacity are expected to outperform rivals (Barney, 1991; Zollo and Winter, 2002).

In a seminal article, Cohen and Levinthal (1990) defined absorptive capacity as "*a firm's ability to recognize the value of new external knowledge, assimilate it and apply it to commercial ends*". They went on to argue that a firm's absorptive capacity is critical to its innovative capabilities and the ability to evaluate and utilize outside knowledge is largely a function of the firm's level of prior related knowledge. At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Furthermore, an organization's absorptive capacity will depend on the absorptive capacities of its individual members. To this extent, the development of an organization's absorptive capacity will build on prior investment in the development of its consistent individual absorptive capacities, and like individuals' absorptive capacities, organizational absorptive capacity will tend to develop cumulatively.

2.6.2 Main Dimensions

Zahra and George (2002) have suggested four dimensions of absorptive capacity, each playing different but complementary roles in explaining how absorptive capacity can influence innovation performance. These four dimensions are, respectively, *acquisition*, *assimilation*, *transformation* and *exploitation*. *Acquisition* refers to a firm's capability to identify relevant external information over the total amount of information that surrounds the firm. In other words, the firm needs to know where the sources of information are. *Assimilation* refers to a firm's routines and processes that allow it to analyze, processing, interpret and understand the information obtained from external sources. *Transformation* consists of the ability to modify and adapt external knowledge and combine it with existing and internally generated knowledge. Finally, *Exploitation* refers to the ability to transform this knowledge into competitive advantage. The first two dimensions sum up to what they label "*Potential Absorptive Capacity*" (PAC). The other two dimensions constitute "*Realized Absorptive Capacity*" (RAC). Whereas PAC makes a firm receptive to external knowledge flows, and RAC reflects the efficiency in leveraging externally absorbed knowledge (Fosfuri and Tribo, 2008). Figure 2.10 illustrates the transformation of external knowledge to innovation outcomes through firm's absorptive capacity.



Source: Based on Zahra and George (2002); Fosfuri and Tribo (2008)

Figure (2.10): From External Knowledge to Innovation Outcomes

2.6.3 Systemic Absorptive Capacity

Many scholars and researchers have explored the components of absorptive capacity using a range of units of analysis: organizational (Cohen and Levinthal, 1990); co-evolution of organization and environment (Van den Bosch et al., 1999); across intra-organizational levels (Kim, 1998); and inter-organizational pairs (Lane and Lubatkin, 1998). Newey et al. (2004) extended this research by shifting the analysis from single firms (Cohen and Levinthal, 1990; Zahra and George, 2002) or alliances (Lane and Lubatkin, 1998) to the synergistic knowledge absorptive capacity of the R&D system as a whole. This is a situation where multiple firms may lead the innovative process throughout development and where multiple alliances occur to link their respective contributions. Inter-organizational transfers of the developing product through milestones take on the property of a system as decisions made by earlier lead innovators affect the ability of later lead innovators to efficiently use their absorptive capacity. Path dependence between changing lead innovators suggests an inter-organizationally cumulative and synergistic property in the use of absorptive capacity across temporally distinct, but interlinked, alliances in product development. This inter-organizationally cumulative and synergistic property is called "*Systemic Absorptive Capacity*".

2.6.4 Absorptive Capacity Interactions

According to Nieto and Quevedo (2005), table 2.1 brings together details of practically all the research studies undertaken recently on the interactions of absorptive capacity concept with other associated concepts.

INTERACTIONS OF ABSORPTIVE CAPACITY CONCEPT
Author: Cohen and Levinthal (1989, 1990) *Sample:* 1302 business units in 297 industrial companies in the USA *Measure:* Impact on R&D expenditure of certain characteristics of the learning environment. *Basic Interaction:* Relates R&D spending/sales with absorptive capacity. *Results:* Factors affecting ease of learning impact on the R&D spending as a pro-portion of sales. Hence, absorptive capacity exists and is relevant.
Author: Atuahene-Gima (1992) *Sample:* Theoretical analysis *Measure:* Not included *Basic Interaction:* Relates adoption of internal technology licences to absorptive capacity, and to internal capacity to develop new products. *Results:* The existence of absorptive capacity is a basic condition for adoption of internal technology licences.
Author: Nicholls-Nixon (1993) *Sample:* Multinational pharmaceutical companies *Measure:* 1) Patents. 2) Development of new products. 3) Reputation. *Basic Interaction:* Relates absorptive capacity to the advantage taken (level of learning) of research alliances.

Results: Companies with greater absorptive capacity invest more in R&D, cooperate more on R&D and get more out of alliances.
Author: Mowery, Oxley and Silverman (1996) *Sample:* Bilateral alliances established between 1985 and 1986 in which one of the firms is from the USA. *Measure:* Patents of firm A cited in patents of firm B/Total citations presents in firm B's patents before the agreement. *Basic Interaction:* Relates overlaps in the technological interests of those cooperating to several variables such as nationality of participants, structure of the agreement, investment on R&D and absorptive capacity. *Results:* Absorptive capacity is important in allowing the co-operating parties to get technological capabilities out of an agreement.
Author: Szulanski (1996) *Sample:* 122 transfers of 38 management practices involving 8 originating firms. *Measure:* Set of items rated on a scale from 1 to 5. *Basic Interaction:* Analyzes factors hindering knowledge transfer between different organizational units of a single firm and groups them in four sets: characteristics of the knowledge, characteristics of the context, characteristics of provider, and characteristics of the receiver (absorptive capacity seen as part of last). *Results:* Absorptive capacity of the receiver is one of the principal factors explaining rigidities in companies (firm stickiness) over transfer of knowledge between their organizational units.
Author: Veugelers (1997) *Sample:* 290 firms with outlays on R&D in the Netherlands between 1992 and 1993. *Measure:* 1) Links with basic research. 2) Presence of an R&D department. 3) Number of PhDs in the R&D area. *Basic Interaction:* Relates R&D spending to absorptive capacity. *Results:* Co-operation on R&D has positive effects on investment in own R&D only if there is absorptive capacity.
Author: Luo (1997) *Sample:* Joint ventures established in China between local firms and multinationals between 1988 and 1991. *Measure:* Technology staff/Total staff *Basic Interaction:* Impact of given characteristics of local firms (absorptive capacity, market strength, size, etc.) on the success of cooperation agreements. *Results:* The absorptive capacity of the local associate is vital for good running of any joint venture.

Author: Cockburn and Henderson (1998) *Sample:* Ten large pharmaceutical firms. *Measure:* Total publications per dollar spent on R&D per year. *Basic Interaction:* Examines the relationship between public R&D, private R&D and absorptive capacity. *Results:* 1) Only firms with absorptive capacity are able to have access to or connect with basic research carried out by public laboratories. 2) The degree to which private companies tap into the work of public laboratories is correlated to their absorptive capacity.
Author: Koza and Lewin (1998) *Sample:* Theoretical analysis *Measure:* Not included *Basic Interaction:* Relates the aims of alliances (exploratory/exploitation) to the form of the co-operation agreement (absorptive capacity of participants, systems of control and identification). *Results:* Not included
Author: Kumar and Nti (1998) *Sample:* Theoretical analysis *Measure:* Not included *Basic Interaction:* Relates the stability and evolution of an alliance to conflicts relating to the ability of those co-operating to attain their learning objectives (linked to their absorptive capacity). *Results:* Not included
Author: Lane and Lubatking (1998) *Sample:* International co-operation agreements for R&D set up between pharmaceuticals firms involved in developing therapeutic products between 1985 and 1993. *Measure:* 1) Overlap of product characteristics. 2) Formalization of management practices. 3) Degree of centralization of decision-taking. 4) Similarities in pay and benefit packages. *Basic Interaction:* Relates absorptive capacity with success within the firms in the alliance (in learning organizational skills). *Results:* The factors determining success in the relation-ship are the following: 1) Relevance of the learning firm's basic knowledge to the teaching firm's. 2) Similarity in pay and benefits practices. 3) Similarity in areas of research. 4) Similarity between organizational structures.
Author: Shenkar and Li (1999) *Sample:* Ninety Chinese firms seeking partners for cooperation agreements. *Measure:* Knowledge brought by local associate (Binary variables according to whether or not the local contact brings various knowledge types). *Basic Interaction:* Relates the type of associate that the local firm will seek to the knowledge that

it possesses; a partner complementing knowledge it already has or aiding it to expand this knowledge. *Results:* Firms seek knowledge in areas complementary to their own rather than in their own area of specialization.
Author: Mangematin and Nesta (1999) *Sample:* 400 R&D contracts drawn up between the French National Centre for Scientific Research and firms located in the area of Grenoble. *Measure:* 1) R&D Spending. 2) Number of researchers. 3) Number of R&D laboratories. 4) Permanence of R&D activity. 5) Relations with public research institutes. 6) Number of publications, number of patents. *Basic Interaction:* Analyzes the relationship among three features: the tacit or codified nature of knowledge, its basic or applied status and the firms' absorptive capacity. *Results:* The presence of considerable absorptive capacity inhibits cooperation on R&D. Moreover, given this circumstance it is possible to absorb all sorts of knowledge, both basic and, through a whole range of vehicles (doctoral students, machinery, and scientific staff). There is also a diversification of the mechanisms by which such absorption can occur.
Author: Becker and Peters (2000) *Sample:* 2900 innovative manufacturing firms (data from the Mannheim Innovation Panel [MIP] gathered in Germany in 1993). *Measure:* 1) Existence of permanent R&D departments. 2) R&D activities carried out continuously. *Basic Interaction:* The relation between the level of technological opportunity in a sector and innovative activity by firms (investments made and results obtained) and how this relationship is influenced by the presence of absorptive capacity. *Results:* Regressions not including absorptive capacity indicate that sources linked to scientific knowledge have a very strong influence on the innovative activity of German manufacturing companies. When absorptive capacity is included there is an increased probability that the firm will carry out R&D actions. There is a positive relation between absorptive capacity and output of innovations.
Author: Stock et al. (2001) *Sample:* Firms that between 1976 and 1993 developed modems and brought them onto the market. *Measure:* R&D Spending/Sales. *Basic Interaction:* The relationship between absorptive capacity in a company and its efficiency in the process of developing new products. *Results:* 1) The relationship between absorptive capacity and efficiency in developing new products is not linear. 2) An inverted U curve is found, suggesting diminishing returns for absorptive capacity.

Source: Nieto and Quevedo (2005)

Table (2.1): Research on Variable Absorptive Capacity

2.7 SCIENCE AND TECHNOLOGY STRATEGIES WORLDWIDE

Australia:

The government of Australia has developed the national strategy for science and technology to cover a period of 2004-2010 (COA, 2001). This strategy supports the essential ingredients for a dynamic and productive innovation system. It focuses on the Government's commitment to three key elements in the innovation process:

– *Strengthening Australia ability to generate ideas and undertake research through*:1) Supporting internationally competitive research; 2) Providing the infrastructure needed to support project-funded research; 3) Upgrading the basic infrastructure of universities such as scientific and research equipment, libraries and laboratory facilities; 4) Ensuring Australia participation in key emerging technologies; 5) Providing researchers with the most up-to-date equipment and facilities; and 6) Providing a significant incentive for business to increase their R&D investment.

– *Accelerating the commercial application of ideas through*:1) Enhancing continually the spin-off opportunities from industry research collaboration; 2) Providing early assistance to firms by improving their commercialisation skills; 3) Ensuring access to the best overseas technology and science; 4) Helping commercialise public sector research through "*pre-seed*" funding; 5) Ensuring that recent changes to the tax system will encourage venture capital investment; 6) Ensuring Australia has a regulatory environment that allows to maximise the outcomes of innovation; and 7) Strengthening Australia's IP protection system,

– *Developing and retaining Australian skills through*: 1) Increasing the number of graduates in areas where Australia faces shortages; 2) Encouraging lifelong learning and to help Australians upgrade and acquire new skills; 3) Attracting and retaining leading researchers in key positions; 4) Fostering scientific, mathematical and technological skills, developing school based innovation and building supportive school environments; 5) Enhancing student access to quality learning opportunities and providing experience of information & communication Technology (ICT) as a learning tool; 6) Enhancing student access to quality learning opportunities and providing experience of ICT as a learning tool; and 7) Raising the understanding of the importance and commercial potential of science and technology, particularly amongst the young people.

Canada:

The government of Canada has worked to develop a national innovation strategy for the 21st century. This strategy is to cover a period of 2000-2010 (Industry of Canada, 2001). The overall objective of this strategy is to ensure that Canada is recognized as one of the most innovative countries in the world. The national innovation strategy of Canada elaborates on Canada's innovation challenge and proposes goals, targets and federal priorities in the following four principal areas:

– *Knowledge performance challenge*: Creating and using knowledge strategically to benefit Canadians through promoting the creation, adoption, and commercialization of knowledge. The following federal initiatives to help more firms develop, adopt and market leading-edge innovations: 1) Address key challenges for the university research environment through; support of the indirect costs of university research, i.e. contributing to a portion of the indirect costs of federally supported research, taking into account the particular situation of smaller universities; leverage of the commercialization potential of publicly funded academic research, i.e. support of academic institutions in identifying intellectual property with commercial potential and forging partnerships with the private sector to commercialize research results; provide of internationally competitive research opportunities in Canada, i.e. increasing support to the granting councils to enable them to award more research grants at higher funding levels. 2) Renew the government of Canada's science and technology capacity to respond to emerging public policy, stewardship and economic challenges and opportunities: The government of Canada will consider a collaborative approach to investing in research in order to focus federal capacity on emerging science-based issues and opportunities. The government would build collaborative networks across government departments, universities, non-government organizations and the private sector. 3) Encourage innovation and the commercialization of knowledge in the private sector through; providing greater incentives for the commercialization of world-first innovations, i.e. the government of Canada will consider increased support for established commercialization programs that target investments in biotechnology, information and communications technologies, sustainable energy, mining and forestry, advanced materials and manufacturing, aquaculture and eco-efficiency; providing more incentives to small and medium-sized enterprises (SMEs) to adopt and develop leading-edge innovations, i.e. the government of Canada will consider providing support to the National Research Council Canada's industrial research assistance program to help Canadian SMEs assess and access global technology, form international R&D alliances, and establish international technology-based ventures; rewarding Canada's innovators, i.e. the government of Canada will consider implementing a new and prestigious national award, given annually, to recognize internationally competitive innovators in Canada's private sector; and increasing the supply of venture capital in Canada, i.e. the business development bank of Canada (BDBC) will pool the assets of various partners, invest these proceeds in smaller, specialized venture capital funds, and manage the portfolio on behalf of its limited partners.

– *The skills challenge:* To succeed in the global, knowledge-based economy, where highly skilled people are more mobile than ever before, a country must produce, attract and retain a critical mass of well-educated and well-trained people. The government of Canada proposes the following federal initiatives to develop, attract, and retain the highly qualified people required to fuel Canada's innovation performance: 1) Produce new graduates through; providing financial incentives to students registered in graduate studies programs, and double the number of master's and doctoral fellowships and scholarships awarded by the federal granting councils; creating a world-class scholarship program of the same prestige and scope as the Rhodes Scholarship, supporting and facilitating a coordinated international student recruitment strategy led by Canadian universities, and implementing changes to immigration policies and procedures to facilitate the retention of international students; and establishing a cooperative research program to support graduate and post-graduate students and, in special circumstances, undergraduates, wishing to combine formal academic training with extensive applied research experience in a work setting. 2) Modernize the Canadian immigration system through; maintaining its commitment to higher immigration levels and work toward increasing the number of highly skilled workers; expanding the capacity, agility and presence of the domestic and overseas immigration delivery system to offer competitive service standards for skilled workers, both permanent and temporary; branding Canada as a destination of choice for skilled workers; and using a redesigned temporary foreign worker program and expanded provincial nominee agreements to facilitate the entry of highly skilled workers, and to ensure that the benefits of immigration are more evenly distributed across the country.

– *The innovation environment challenge:* The government of Canada proposes the following federal initiatives to protect Canadians and encourage them to adopt innovations; encourage firms to invest in innovation; and attract the people and capital upon which innovation depends: 1) Ensure effective decision making for new and existing policies and regulatory priorities, i.e. support a *"Canadian Academies of Science*" to build on and complement the contribution of existing Canadian science organizations; undertake systematic expert reviews of existing stewardship regimes through international benchmarking, and collaborate internationally to address shared challenges. 2) Ensure that Canada's business taxation regime is internationally competitive, i.e. the government of Canada will work with the provinces and territories to ensure that Canada's federal, provincial and territorial tax systems encourage and support innovation. 3) Brand Canada as a location of choice: The government of Canada has committed to a sustained investment branding strategy. This could include investment team Canada missions and targeted promotional activities.

– *Strengthening communities challenge:* Communities where the elements of a national, globally competitive innovation system are come together. To become magnets for investment and growth, communities need a critical mass of entrepreneurship and innovation capabilities. The government of Canada proposes the following federal initiatives to support innovation in communities across the country: 1) Support the development of globally competitive industrial clusters: The government of Canada will accelerate community-based consultations already under way to develop technology clusters where Canada has the potential to develop world-class expertise, and identify and start more clusters. 2) Strengthen the innovation performance of communities: The government of Canada will consider providing funding to smaller communities to enable them to develop innovation strategies tailored to their unique circumstances; communities would be expected to engage local leaders from the academic, private and public sectors in formulating their innovation strategies; additional resources, drawing on existing and new programs, could be provided to implement successful community innovation strategies; and as part of this effort, the government of Canada will work with industry, the provinces and territories, communities, and the public to advance a private sector solution to further the deployment of broadband, particularly for rural and remote areas.

India:

Recognizing the changing context of the science and technology, India has developed its national S&T policy 2003 to meet future national needs in the new era of globalization (MSTI, 2003). Some of the key elements of the implementation strategy are as follows:

– *Science and technology governance and investments:* Suitable mechanism will be evolved by which independent inputs on science and technology policy and planning are obtained on a continuous basis from a wide cross section of scientists and technologists. It will utilize the academies and specialized professional bodies for this purpose. These inputs will form an integral part of the planning and implementation of all programmes relating to science and technology, as also in government decision making and formulation of policies in socio-economic sectors.

– *Optimal utilization of existing infrastructure and competence*: Science and technology is advancing at a very fast pace, and obsolescence of physical infrastructure, as also of skills and competence, take place rapidly. Steps will be taken to network the existing infrastructure, investments and intellectual strengths, wherever they exist, to achieve effective and optimal utilization, and constantly upgrade them to meet changing needs.

– *Strengthening of the infrastructure for science and technology in academic institutions:* A major initiative to modernize the infrastructure for science and engineering in academic institutions will be undertaken. It will be ensured that all middle and high schools, vocational and other colleges will have appropriately sized science laboratories. Science, engineering and medical departments in academic institutions and universities and colleges will be selected for special support to raise the standard of teaching and research.

– *New funding mechanisms for basic research*: The setting up of more efficient funding mechanisms will be examined, either by creating new structures or by strengthening or restructuring the existing ones, for promotion of basic research in science, medical and engineering institutions. In particular, administrative and financial procedures will be simplified to permit efficient operation of research programmes in diverse institutions across the country.

– *Human resource development:* For building up the human resource base in relevant areas, the agencies and departments concerned with science and technology will make available substantial funding from their allocation. Flexible mechanisms will be put in place in academic and research institutions to enable researchers to change fields and bring new inputs into traditional disciplines, and also to develop inter-disciplinary areas. There will be emphasis on a continuing process of retraining and re-skilling to keep pace with the rapid advances taking place. Wherever considered necessary, training abroad will be resorted to, so as to build up a skilled base rapidly.

– *Technology development, transfer and diffusion:* A strong base of science and engineering research provides a crucial foundation for a vibrant programme of technology development. Priority will be placed on the development of technologies which address the basic needs of the population; make Indian industries - small, medium or large - globally competitive; make the country economically strong; and address the security concerns of the nation. Special emphasis will be placed on equity in development, so that the benefits of technological growth reach the majority of the population, particularly the disadvantaged sections, leading to an improved quality of life for every citizen of the country. These aspects require technology foresight, which involves not only forecasting and assessment of technologies but also their social, economic and environmental consequences. The transformation of new ideas into commercial successes is of vital importance to the nation's ability to achieve high economic growth and global competitiveness. Accordingly, special emphasis will be given not only to R&D and the technological factors of innovation, but also to the other equally important social, institutional and market factors needed for adoption, diffusion and transfer of innovation to the productive sectors.

– *Promotion of innovation:* Innovation will be supported in all its aspects. A comprehensive national system of innovation will be created covering science and technology as also legal, financial and other related aspects. There is need to change the ways in which society and economy performs, if innovation has to fructify.

– *Industry and scientific R&D:* Every effort will be made to achieve synergy between industry and scientific research. Autonomous Technology Transfer Organizations will be created as associate organizations of universities and national laboratories to facilitate transfer of the know-how generated to industry. Increased encouragement will be given, and flexible mechanisms will be evolved to help, scientists and technologists to transfer the know-how generated by them to the industry and be a partner in receiving the financial returns. Industry will be encouraged to financially adopt or support educational and research institutions, fund courses of interest to them, create professional chairs etc. to help direct S&T endeavours towards tangible industrial goals.

– *Indigenous resources and traditional knowledge:* Indigenous knowledge, based on India's long and rich tradition, would be further developed and harnessed for the purpose of wealth and employment generation. Innovative systems to document, protect, evaluate and to learn from India's rich heritage of traditional knowledge of the natural resources of land, water and bio-diversity will be strengthened and enlarged.

– *Technologies for mitigation and management of natural hazards:* Science and technology has an important role in any general strategy to address the problems of mitigation and management of the impacts of natural hazards. A concerted action plan to enhance predictive capabilities and preparedness for meeting emergencies arising from floods, cyclones, earthquakes, drought, landslides and avalanches will be drawn up. Measures will be undertaken to promote research on natural phenomena that lead to disasters and human activities that aggravate them. This will be with a view to developing practical technological solutions for pre-disaster preparedness, and mitigation and management of post- disaster situations.

– *Generation and management of intellectual property:* Intellectual Property Rights (IPR), have to be viewed, not as a self-contained and distinct domain, but rather as an effective policy instrument that would be relevant to wide ranging socio-economic, technological and political concepts. The generation and fullest protection of competitive intellectual property from Indian R&D programmes will be encouraged and promoted.

– *Public awareness of science and technology:* There is growing need to enhance public awareness of the importance of science and technology in everyday life, and the directions where science and technology is taking us. People must be able to consider the implications of emerging science and technology options in areas which impinge directly upon their lives, including the ethical and moral, legal, social and economic aspects. In recent years, advances in biotechnology and information technology have dramatically increased public interest in technology options in wide ranging areas.

– *International science and technology cooperation:* Scientific research and technology development can benefit greatly by international cooperation and collaboration. Common goals can be effectively addressed by pooling both material and intellectual resources. International collaborative programmes, especially those contributing directly to scientific development and security objectives, will be encouraged between academic institutions and national laboratories in India and their counterparts in all parts of the world, including participation in mega science projects as equal partners. Special emphasis will be placed on collaborations with other developing countries, and particularly neighbouring countries, with which India shares many common problems. International collaboration in science and technology would be fully used to further national interests as an important component of foreign policy initiatives.

– *Fiscal measures:* Innovative fiscal measures are critical to ensure successful implementation of the policy objectives. New methods are required to stimulate R&D activities, particularly in industry. New strategies have to be formulated for attracting higher levels of public and private investments in scientific and technological development. A series of both tax and non-tax fiscal instruments have to be evolved to ensure a leap-frogging process of development.

– *Monitoring:* Effective, expeditious, transparent and science-based monitoring and reviewing mechanisms will be significantly strengthened, and wherever not available will be put in place. It will be ensured that the scientific community is involved in, and responsible for, smooth and speedy implementation.

Indonesia:

Indonesia has developed its S&T policy for the period of 2005-2025 in order to survive in the S&T global competitiveness arena, to adapt changes and meet the global S&T development needs in a world shifts from natural resource based development to knowledge based development (ISMRT, 2006). The vision, mission and values of Indonesian S&T 2025 are addressed as follows:

– *Vision*: To establish science and technology as the main force for sustainable prosperity.

– *Missions*: 1) To place S&T as the basis for the policy of national development in achieving sustainable prosperity; 2) To build ethical foundation for the development and implementation of S&T; 3) To increase S&T diffusion through the consolidation of the network of its actors and institutions, including the development of its mechanism and institutionalization of its intermediary; 4) To build quality and competitive human resources, infrastructures, and institutions for S&T; and 5) To create smart, creative, and competitive Indonesian in a knowledge based society.

– *Values:* visionary, innovativeness, excellence, accountability.

Moreover, S&T policy is based on some crucial factors for Indonesian development as follows: 1) Incentive systems in terms of sound macroeconomic policies to speed investment growth and low inflation; trade regime; and domestic competition policies. 2) Increasing the quality of human resources. 3) Public S&T infrastructures. 4) Increase research and development fund. 5) Strengthen and deepen the partnership of academicians, business and governments. 6) Reduce market failure. 7)

Development of technology oriented for SMEs. 8) International cooperation in S&T development.

Iran:

The fourth five year social, cultural and economic development plan 2005-2009 sought to promote the development of a knowledge society in Iran by strengthening the role of science and technology in the innovation process (UNCTAD, 2005a). This development plan is based on:

– *Improving coordination and coherence in horizontal innovation policymaking:* As in distributed knowledge systems more generally, distributed policymaking enables policy coordination and coherence to take place with a reduced need for centralized, hierarchical decision-making processes. This framework facilitates task-oriented behaviour through management committees that combine the principal of an explicit division of labour with regard to critical policy tasks and functions within the innovation system and the variable geometry that brings together that set of ministries and policies needed to support systems-embedded processes of innovation in and across productive sectors or in problem areas targeted for attention at the national level.

– *Building research and technological capacity through joint ventures, licensing agreements and strategic partnerships with foreign firms and research institutions:* Licensing has been practiced in Iran as a means to produce a variety of products in the oil, gas and petrochemical sector as well as in pharmaceuticals for the domestic market, but incentives for learning through licensing and more recently through joint ventures have been few. The reason for this is related to the continued emphasis in Iran on production rather than on innovation as the core of the development process. More attention has been given to short-term economic benefits from cooperation and licensing, but getting the most out of these agreements in the long term should warrant including them as major instruments in a national innovation policy and designing them accordingly.

– *Building user-producer links:* Innovation is fundamentally an interactive process, and user-producer interactions are at the core of a dynamic innovation system. Users may be downstream enterprises that are clients of upstream firms, as in the link between oil and gas producers and petrochemical firms or between petrochemical firms and downstream industries such as polymers, textiles and automobiles. Policies have a strategic role to play in strengthening these linkages through: 1) Targeting the supply of R&D; as the growing attention in many industrialized countries to the need to build bridges between knowledge producers and users has resulted in a wide range of policy initiatives to spur public-private partnerships and science-industry relations. These include funding mechanisms to stimulate the formation of R&D partnerships. 2) Targeting the demand for technology; while competition pushes firms to innovate, demand pulls new knowledge into economic production. Demand is thus one of the key drivers of innovation. 3) Upgrading SMEs; small enterprise promotion could benefit from the development of market-oriented business development services. Technical cooperation projects can be designed to transform state service agencies into contract consulting and research mechanisms.

– *Developing clusters and incubators of knowledge-based activitie*s: Clusters are the result of a spontaneous tendency of SMEs to locate close to each other, but there are also organized efforts to set up clusters from scratch, mainly through incubators and technopoles or science parks, which are artificial agglomerations of firms resulting from technology and export policies.

Japan:

The third science and technology basic plan 2006-2010 for Japan (CSTP, 2005) has been established to highlight: 1) How to nurture creative S&T personnel. 2) Further reform of S&T systems, leading to higher performance irrespective of Japanese serious situation due to limited resources.

The outline of the third science and technology basic plan are as follows:

– *Strategic priority setting in S&T:* 1) Promotion of basic research that would create a great variety of knowledge and lead to breakthroughs. 2) Prioritization of R&D activities for policy-oriented subjects, i.e. R&D resources should be intensively allocated to the primary prioritized areas. 3) Promotion strategy for the prioritized areas.

– *S&T system reforms:* 1) Fostering S&T personnel and providing opportunities through more opening for conducting research as an independent principal investigation, increasing grant for young research, expand opportunities for female researchers, attract foreign researchers to work in Japan, providing opportunities for excellent senior researchers, making research environments more competitive, nurture human resources who excel in diverse fields adequately responding to social needs, further reform of university system for stronger competitiveness, enhancing of industry-academia- government collaboration, activation of the regional S&T mainly conducted by local universities, drastic reform of public research institutes to strengthening their functions, and upgrading of government-wide R&D data base for efficient and appropriate budget allocation. 2) Progress in science leading to innovation. 3) Upgrading infrastructures for S&T promotion through providing equipment & facilities, and improving intellectual infrastructures and research-informational infrastructures including network & data base. 4) Strategic commitment on international S&T activities.

– *Public confidence and engagement:*1) Responsible actions regarding ethical, legal and social issues. 2) Reinforcement of accountability and public relations of S&T activities. 3) Promotion of public understanding of S&T. 4) Facilitation of public engagement with S&T-related issues. 5) Strategic commitment on international S&T activities, such as ministerial meeting among Asian countries, to challenge common agenda and to respond to expectations of international society.

Malaysia:

The second national science and technology policy for the 21st century in Malaysia for a period of 2000-2010 puts in place programmes, institutions and partnerships to enhance Malaysia economic position including the quality of life of the people (GOM, 2000). This policy addresses seven key priority areas:

– *Strengthening research and technological capacity and capability* through: 1) Increasing public and private investment in R&D including infrastructure development. 2) Research and technology development programmes including basic research in the new and emerging technologies to be prioritised regularly to ensure focus in areas which can yield highest socioeconomic payoffs. 3) Launching, jointly with industry associations. new programmes in selected sectors to strengthen indigenous technological capabilities of local corporations in existing as well as new and emerging technologies through partnerships with universities and public research institutes (PRIs) as well as through creative engineering. 4) Stimulating private sector investment in R&D or technology development through: Enhancing access to public research facilities; financial contribution from the private sector; ensure that the fund is used solely for R&D purposes for that particular industry; yearly report to ensure accountability; supporting industry initiatives including those of industry associations to develop specific facilities to strengthen technological capabilities; promoting competitiveness through science, technology and innovation; review existing fiscal and financial incentives for R&D so that they would promote greater industry investments in R&D as well as attract significant R&D projects to Malaysia; and enlarge allocations for industry grant schemes e.g. industry research and development grant scheme (lGS), multimedia super corridor research and development grant scheme (MGS), demonstrator application grant scheme (DAGS). 5) Aggressive and strategic implementation of existing Technology Acquisition Programme under the smart partnership framework with Malaysian companies and government-controlled agencies. 6) Establishing strong linkages with regional and international centres of excellence in collaborative R&D as well as co-development of technology.

– *Promoting commercialisation of research outputs* through: 1) Establishment of business development unit within ministry of science, technology and environment (MOSTE) to develop strategies and programmes aimed at enhancing the commercialisation and diffusion of research findings generated from public funded research organisations. Such programmes include, among others: The introduction of a new reach out programme to support the efforts of business innovation units in universities and PRIs; Establishing new mechanisms (e.g. best practice centres) to provide universities and PRIs with support in commercialising research outputs; Establishment of a pre-seed capital fund for universities, PRIs and Innovation or best practice centres which are to be allocated on a competitive basis; study on establishment of holding company under MOSTE to promote commercialisation of research findings from universities and PRIs; and Improving incentives for researchers to commercialise their findings. 2) Introduce, in collaboration with Association for small and medium enterprises (SMEs), a public sector-industry partnership programme where researchers will spend some time providing technical assistance to companies. 3) Incorporate within existing procurement practices, programmes to support innovation and development of indigenous technology development. 4) Apply self-financing targets (operating budget) for all public research institutions (30 per cent by 2005) and universities (15 per cent by 2005).

– *Developing human resource capacity and capability* through: 1) Intensify development of critical mass for S&T. 2) Expand implementation of S&T human resource development (HRD) Fund. 3) Strengthen and expand teaching company scheme and other student attachment programmes to build long-term relationships for technology transfer and training between university and industry. 4) Improve the career prospects and mobility of scientists and research workers. 5) Re-examine programme on retuning Malaysian scientists to make it more attractive through targeted fiscal and non-fiscal incentive. 6) Review the skills development fund to finance industry-training programmes. This would be jointly managed by the private sector and the government, with manufacturing industries contributing one per cent of their total payroll to the fund. Existing facilities at industrial training and other institutes can be made available for fund-supported programmes, and in-house training programmes may also qualify for support. Serious consideration can also be given to private sector. 7) Enhance and modernise the existing system of certification of technical personnel and classification of skills. This will greatly facilitate the development of a technically proficient and mobile workforce. 8) Expand adult and continuing education programmes, particularly in technical subjects, to upgrade the skill base in specific areas. The provision of adequate facilities has to go hand in hand with an enlightened management and the realisation that personal fulfilment leads to greater job satisfaction and a positively motivated employee. 9) Strengthen the effectiveness of mechanisms to allow industry to contribute to course design and curriculum review in institutions of higher learning and industrial training institutes. 10) Ensure that Malaysian graduates acquire training and skills that are fully relevant to national needs, particularly with respect to the choice of elective subjects and post-graduate programmes and fields of research. 11) Enhance and institutionalise linkages for industrial training between industry and educational establishments. Courses at institutions of higher learning should include a high degree of exposure to practical situations through relevant practical training opportunities. 12) Strengthen the role of tertiary institutions in advanced technology research and innovation. 13) Ensure an effective role for institutions of higher learning in all proposed technology parks and innovation centres. Special attention must be given to the cultivation of skills related to technological reproduction, adaptation and innovation. Universities must adopt a more commercial stance in developing technologies.

– *Promoting a culture for science, innovation and techno-entrepreneurship* through: 1) Expand the scope and coverage of S&T promotion activities. 2) Promote techno-entrepreneurship through; provision of techno-entrepreneurship courses to all science, technology and engineering undergraduates; conduct annual techno-entrepreneurship competition; Amendments to university or PRI personnel service scheme that enable selected staff to take sabbatical leave with no loss of seniority in order to commercialise a research findings; Ensuring existing public venture capital funding and banking system to provide window for early seed financing as well as support for technology development; Establishment of Malaysian technology credit guarantee scheme through existing mechanism to support formation of new technology based firms (NTBFs); Introduce a more innovative mode of financing such as debt ventures funding with flexibility in the lending facilities; Encourage local corporations to set up angel investment funds by publicising the incentives through seminars, workshops and newsletters; Create an avenue to showcase companies to angel investors and venture capitalists; and Review achievement of ventures capital fund and other incentives to encourage commercialisation of R&D output. 3) Increase science and technology awareness and appreciation at all levels of government. The objective is the permeation of a science and technology consciousness into the structure for national decision making and implementation of development programmes. This can be achieved by a wide ranging series of measures, including special courses on S&T at public science institutes and the appreciation on the S&T dimension in general courses at such institutes. 4) Raise S&T awareness and appreciation by inculcating S&T culture in the education system. 5) Use the mass media to heighten public awareness and appreciation of

Science and Technology. 6) Enhance the scope and coverage of the Science and Technology Week programme and other promotional activities. 7) Encourage the formation and development of centres of excellence in science. 8) Promote the formation of guilds for technical personnel with activities that are specially focussed on technical and professional issues. 9) Support the Malaysia Design Council that aims to create and maintain a fund to be used for encouraging the creation, design, development, financing manufacture and utilisation of Malaysian inventions, research results and other intellectual property.

– *Strengthening institutional framework and management for S&T and monitoring of S&T policy implementation* through: 1) Strengthen the MOSTE by endowing it with necessary resources to ensure effective S&T policy formulation and implementation. 2) Review the role of National Council for Scientific Research and Development to ensure effectiveness of S&T advisory and coordination system. 3) Expand efforts to develop effective information gathering, monitoring and evaluation and transmission mechanism to track the nation's performance in S&T as well as development of new technical development. 4) Promote adoption of sound research management practices including intellectual property management and commercialisation of research outputs in all PRIs and universities. 5) Enhance the management of intellectual property rights including patent advisory and other services. 6) Develop mechanisms and codes of practice to ensure that development of S& T accords emphasis to preventive approaches as well as being consistent with acceptable societal norms and ethics. 7) Enhance the management of the technology intelligence and information system. 8) Require public sector R&D institutes to draw up five-year budget plans detailing research programmes and priorities. 9) Enhance the system of contract research. The objective is to encourage market-driven research through a clear understanding of priority areas, the monitoring of R&D performance, and the introduction of a degree of competitiveness in research activities.10) Aim for a greater degree of financial autonomy for R&D institutes. The decision-making process could thus be speeded up, manpower and skills would be better utilised, and R&D programmes would be more clearly geared towards performance.

– *Ensure widespread diffusion and application of technology, leading to enhanced market-driven R&D to adapt and improve technologies* through: 1) Enhance quality awareness and design in industry through on-going programmes. Quality and standards play an important role in building up international competitiveness, and the level of quality awareness must therefore permeate the full range of activities in Malaysian industry. 2) Form a special technical committee to propose specific and concrete measures to enhance the capability of the engineering and technical services sector. 3) Ensure the effectiveness of the Industrial Technical Assistance Fund. This can be achieved by extending its scope to include a larger range of activities including automation and R&D in targeted areas; broadening coverage to include all firms, while retaining the emphasis on small and medium scale enterprises; increasing the maximum level of matching grant for R&D. 4) Gear public procurement policy firmly to stimulating innovation and product development for local firms to help them be more competitive in regional and international markets. 5) Strengthen linkages between firms by encouraging R&D and product development programmes between purchasers and suppliers and developing vendor support systems. 6) Undertake a detailed scrutiny with a view to implementation of the product group Action Profiles in the key industry sectors.

– *Build competence for specialisation in key emerging technologies* through: 1) Develop a secure knowledge base in the key technology areas to sustain technology support for Malaysian industry. 2) Prioritise research programmes in the new and emerging technologies to ensure focus in areas that yield the highest economic pay-offs. 3) Institute special measures to encourage the formation and development of new technology- based firms engaged in the promotion or commercialisation of technological innovations. 4) Set up national focal points for each of the new and emerging technologies. These would serve as the hub of R&D activity in the respective fields. 5) Enhance exposure to international developments in the new technologies, and exploitation of foreign research expertise where necessary.

United Kingdom:

The UK government's overall strategy for science and innovation (TSB, 2006) for the period of 2004-2014 is to focus on: 1) Help UK's leading sectors and businesses maintain their position in the face of global competition. 2) Stimulate those sectors and businesses with the capacity to be among the best in the world to fulfil their potential. 3) Ensure that the emerging technologies of today become the growth sectors of tomorrow. 4) Combine all these elements in such a way that the UK becomes a centre for investment by world-leading companies.

Moreover, the technology strategy is delivered through the following main activities:

– *Innovation platforms:* The integration of a range of technologies combined with better coordination of policy, regulation and procurement instruments across government to address a major societal challenge and to deliver a step change in UK performance. Innovation Platforms are designed to: 1) Address a major policy and societal challenge. 2) Bring together government stakeholders and funders. 3) Create links between, and better co-ordination of, policy and procurement. 4) Identify the appropriate levers to use. 5) Seek to align funding streams from separate sources. 6) Link research to market through procurement opportunities. 7) Engage with business and the research community to identify appropriate action.

– *Key technology areas:* Strategies for identifying priority technologies and the activities required to ensure wealth generation.

– *Technology programme:* 1) Collaborative R&D: Enables business and research communities to work together on R&D projects from which successful new products, processes and services can emerge. 2) Knowledge Transfer Networks (KTNs): National over-arching networks which aim to improve the UK's innovation performance by increasing the breadth and depth of the knowledge transfer of technology into UK-based businesses. The current stated goals of the KTNs are to; provide UK businesses with the opportunity to meet and network with individuals and organisations, in the UK and internationally; provide a forum for a coherent industry voice to inform government policy making; provide advice on the various support mechanisms available to the research base and business; encourage the flow of people, knowledge and experience between industry and the science base, with the common aim of delivering improved industrial performance; encourage knowledge transfer between the supply and demand sides of technology-enabled markets, through a high quality, easy to use service; and eventually, attract and optimise the use of funding resources by applying professional road-mapping techniques, market analysis tools and methods.

– *Emerging technologies:* Providing the opportunity for businesses to take advantage at an early stage of some of the exciting research that is taking place in the science base. Key to making this happen is: 1) Identification of research at an early stage which shows some commercial potential. 2) Raising awareness of the research with businesses in the UK with the capability to exploit the research. 3) Government support to help de-risk early stage investigation.

Moreover, in accordance with all science and technology strategies demonstrated previously, one can conclude that there are substantially some elements in common that link the trends in these strategies towards science and technology development. Thus, such elements can be largely considered as the essentials for technological development. Table 2.2 summarizes these deductive key elements.

STRATEGY/POLICY	Deductive Key Elements for Technological Development							
	Knowledge Creation	***Driving Innovation***	***Building Skills***	***Promoting Infrastructure***	***International Cooperation***	***Funding R&D***	***Institutional Framework***	***Monitoring Performance***
AUSTRALIA *National Strategy for S&T 2004-2010*	√	√	√	√	√	√	√	×
CANADA *National Innovation Strategy 2000-2010*	√	√	√	√	√	√	√	×
INDIA *National S&T policy 2003*	√	√	√	√	√	√	√	√
INDONESIA *National S&T Policy 2005-2025*	√	√	√	√	√	√	√	×
IRAN *The 4th Social, Cultural and Economic Development 2005- 2009*	√	√	√	√	√	√	√	×
JAPAN *The 3rd S&T Basic Plan 2006-2010*	√	√	√	√	√	√	√	×
MALAYSIA	√	√	√	√	√	√	√	√

The 2nd National S&T Policy for the 21st Century 2000-2010								
UNITED KINGDOM *The UK Government's Overall Strategy for Science and Innovation 2004-2014*	√	√	√	√	√	√	√	×

Table (2.2): Deductive Key Elements for Technological Development

2.8 CONCLUSIONS AND RESEARCH NEEDS

2.8.1 Significance of Capacity Building

In reference to sections 2.2 and 2.3 (pp.18-29), technology has been considered a vital element to national economic performance of countries. Productivity and income of organizations hinge increasingly on their ability to rapidly build up technological competences. This places capacity building at the core of technological development systems. This is not new, but has acquired far greater significance in recent times. For developing countries, the rate of accumulation of technological capabilities has an inherent tendency to translate into economic prosperity gaps across them comparing to their developed counterparts. Narrowing these gaps requires sustainable catch-up efforts of various kinds. Pivotal among these undertakings is a deliberate building of technological capacity.

Moreover, the vision and value this thesis can deliver stem mainly from its objectives and potential outcomes that tapping principally into the pool of catching-up efforts about which developing countries are increasingly still concerned.

2.8.2 Variables for Investigation

Throughout the literature review process some variables have been highlighted in connection with the phenomenon to be investigated. Table 2.3 summarized these variables along with their related areas of interest.

VARIABLE	DEFINITION	AREA OF INTEREST
Basic Research	Experimental or theoretical work undertaken primarily to generate new scientific knowledge about physical,	Research & Development

	biological and social phenomena, without any particular application of that knowledge.	
Applied Research	Geared towards solving particular technological problems and results often in novel or improved technology.	Research & Development
Experimental Development	Refers to the activities involved in putting inventions, discoveries or knowledge to practical use.	Research & Development
R&D Strategy	A comprehensive master plan stating how the corporation will achieve its R&D mission and objectives. In other words, it is the process of setting long-range plans for the effective management of R&D opportunities and threats in light of corporate strengths and weaknesses of the company.	Research & Development
Research Design	To conceive and outline the research structure such as problem formulation, concept & uncertainty mapping, research method, analysis technique, observations manipulation, results evaluation and outcomes expectation.	Research & Development
Experimental Design	To plan the experiment structure such as experiment method, sampling method, estimating measurement uncertainty, verifying validity, assessing reliability of measurement and specifying measurement level & scaling.	Research & Development
Prototype	An original model constructed to include all the technical characteristics and performance of the new product.	Research & Development
Pilot Plant	A trial facility where the new process is tried out and revised.	Research & Development
Research Planning	To allocating and Scheduling resources to complete activities of research project.	Research & Development
Research Monitoring	The process of measuring actual research achievement against planned achievement, analyzing variance, evaluating possible alternatives, and taking appropriate corrective action as needed.	Research & Development
R&D Facilities	They include all physical & intellectual	Research & Development

	facilities used to practice R&D activities	
R&D Space	Encompasses all area dedicated for R&D activities such as laboratories, offices and meeting rooms.	Research & Development
Science-Technology Push Model	Simple linear sequential process; emphasis on R&D. The market is a recipient of the fruits (output) of R&D.	Technological Modelling
Network Model	Emphasis on knowledge accumulation and external linkages.	Technological Modelling
Market Pull Model	Simple linear sequential process; emphasis on marketing. The market is the source for directing R&D which has a reactive role.	Technological Modelling
Interactive Model	Combination of push and pull models.	Technological Modelling
Absorptive Capacity	Team's ability to recognize the value of new external knowledge, assimilate it and apply it to commercial ends.	Technological Competence
Conceptualization Capability	Team's capability to: 1) build shared vision about the research problem, 2) determine and evaluate alternatives to solve that problem, 3) search and explore possible technological opportunities, 4) formulating R&D strategy, and 5) originate research & experimental design.	Technological Competence
Technology Intelligence	A source of information on international R&D activities being executed towards technology development.	Technology Strategy
e-Publications	Showing some selected domestic and/or international publications on the organization's website.	Knowledge Acquisition & Generation
Peer Review	The exchange of tools, methods and experience between policy-makers of peer organizations on the basis of information about relative performance.	Quality Management
Technical Copyright	The rights of intellectual creators in their creation such as books, technical drawings, technical maps, photographic works, software applications, technical motion-pictures, etc.	Intellectual Property Rights
Trademark	A distinctive name, mark or symbol identified with a specific product(s).	Intellectual Property Rights

Inward Technology Transfer	The process of transferring external technology into a particular nation or organization for the purpose of utilization or adaptation.	Inward Technology Openness
Spin-off Enterprises	New small companies established to commercialize the knowledge and skills of a university or corporate research team in terms of new technologies. Many universities, research institutes and large companies establish dedicated seed funds to stimulate spin-off activities.	Commercialization of Technology
Entrepreneurship	The activities that creates new resource combinations to make innovation possible, bringing together the technical and commercial worlds in a profitable way.	Commercialization of Technology
Incubator	A business entity (sometimes called a business innovation centre) created to nurture business ideas or new technologies, with the goal of helping those ideas become attractive to venture capitalists. An incubator typically provides physical space and a variety of other services – such as administrative, legal, business, technical – that incubating companies can draw upon to develop their business ideas	Commercialization of Technology
Venture Capital	A long term equity capital invested in new or rapidly expanding enterprises. It is the lifeblood of entrepreneurs.	Commercialization of Technology
Technological Institutional Set-up	All related legislations, regulations (e.g., intellectual property rights), and policies that aim to sustain creating a right environment to innovation & technology investment.	Role of Government
Job Satisfaction	A sort of feeling generated inside individuals due to their satisfaction with: 1) tasks assigned to them, 2) skills gained, 3) impact of their job on their organization income, 3) degree of choice and control over their job, 4) incentives rewarded to them, 5) quite accepted and possible goals.	Work Environment
Organization Culture	A set of shared and relatively enduring patterns of basic values, beliefs and assumptions in an organization.	Work Environment

Organizational Learning	Enhancing the organization's range of possible responses to threats and opportunities.	Work Environment
Learning Climate	A climate within the organization that support or force learning.	Work Environment

Table (2.3): Variables to be investigated for Technological Competence

2.8.3 Weakness of Innovation System Approach

The system of innovation (SI) approach is still associated with conceptual weakness. For instance, the term "*institution*" is used in different senses by different authors; it is sometimes referred to organization as well as to institutional set-up (see Lundvall, 1992, p.10; Nelson and Rosenberg, 1993, p.5, pp.9-13; Edquist, 1997b, pp.26-28; Patel and Pavitt 1994, pp.79-80).

Although a system is normally considered to have a function, this was not addressed in a systematic manner in the early work on systems of innovation. Somewhat later, some hints in this direction were made by Galli and Teubal (1997). Liu and White (2001) as cited in Edquist (2005, p.189) address what they call a fundamental weakness of national innovation system research, namely "*the lack of system-level explanatory factors*". To remedy this, they focus upon the "*activities*" in the systems, activities being related to the creation, diffusion and exploitation of technological innovation within a system. On this basis, they compile a list of five fundamental activities in innovation systems.

Johnson and Jacobsson (2003) as cited in Edquist (2005, p.189) emphasize that, for an innovation system "*to support the growth of an industry, a number of functions have to serve within it, e.g. the supply of resources*". They suggest that *"a technology or product specific innovation system may be described and analysed in terms of its 'functional pattern', i.e. in terms of how these functions are served*". These authors present a list of five functions. Rickne (2000) as cited in Edquist (2005, p.189) provides a list of eleven functions that are important for new technology-based firms (i.e. not for innovations in an immediate sense). Clearly, there is no consensus to which functions or activities should be included in a system of innovation and this provides abundant opportunities for further research (Edquist, 2005).

Edquist (2005) stresses that; more research should be done on the activities in systems of innovation, i.e. on the determinants of development, diffusion, and use of innovations. He added, a stronger focus on activities would increase our knowledge of, and capacity for, explaining innovation processes. Relevant questions to ask would include: Which activities of which organizations are important for the development, diffusion, and use of specific innovation? Is it possible distinguished between important activities and less important ones? Which institutional rules influence the organizations in carrying out these activities? Such work could further develop the system of innovation approach and contribute to the creation of partial theories about relations between variables within systems of innovation. Such theories would also improve our ability to specify the boundaries of innovation systems.

By reviewing all literature mentioned earlier (see section 2.5, pp.33-54), one can conclude that most of system innovation concepts – in particular NSI concept, SSI concept and TIM concept – are essentially *structure-based views*. They focus on demonstrating the system structure including actors, interactions and institutional set-up rather than paying attention to elaborate the innovation activities (causes and determinants of innovation) in terms of *activity-based view*. Table (2.4) highlights such kind of conclusion.

CONCEPT	MAIN FOCUS	APPROACH TYPE
NATIONAL SYSTEM OF POLITICAL ECONOMY Liszt (1841)	A wide set of national institutions (organizations), infrastructure such as networks for transportation of people and commodities, and the relevance of knowledge, the links between scientific institutions and productive sector and foreign technologies for economic development.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Freeman (1987)	The network of institutions (organizations), in the public and private sectors and their activities and interactions for technology creation.	• Structure-based view (i.e. wholly considered) • Activity-based view (i.e. partly considered)
NATIONAL SYSTEM OF INNOVATION	The emphasis on user-producer interaction within the national economy and	• Structure-based view

Lundvall (1985, 1988)	technological flows and technology development interactions among firms.	(i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Niosi and Bergeron (1992)	A study on technical alliances in the Canadian electronics industry.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Porter (1990)	The importance of the local supply of skills, specific local demands, and the pressure of competition for the national system of innovation.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Niosi et al. (1993)	Interaction of private and public firms, universities, and government agencies aiming at the production of science and technology within national borders.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Nelson (1993)	A set of institutional actors that, together, plays the major role in influencing innovative performance. Additionally, sectors and technological systems, within a nation, have a powerful shaping influence on the structure and dynamics of a national innovation system, whilst national context have important influences on sectoral conditioning and performance.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Patel and Pavitt (1994)	The national institutions, their incentives structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change-generating activities) in a country.	• Structure-based view (i.e. wholly considered) • Activity-based view (i.e. partly considered)
NATIONAL SYSTEM OF INNOVATION Edquist (1997a)	The NSI is not a formal theory but rather a conceptual framework for addressing the issues in question from a holistic, interdisciplinary and historical standpoint. Some common characteristics of the systems of innovation approach were outlined.	• Structure-based view (i.e. wholly considered) • Activity-based view (i.e. partly considered)
NATIONAL SYSTEM OF INNOVATION Liu and White (2001)	Address a fundamental weakness of national innovation system research, namely "the lack of system-level explanatory factors". Providing a list of five fundamental activities for innovation creation.	• Activity-based view (i.e. wholly considered in non-profound manner)

NATIONAL SYSTEM OF INNOVATION Balzat (2002)	The definition of national innovation system should contain and emphasize the consideration of the entire innovative process; the analysis of various main actors involved in these processes (plus the linkages between them); and the institutional set-up serving as a framework for economic action.	• Structure-based view (i.e. wholly considered) • Activity-based view (i.e. emphasis only)
NATIONAL SYSTEM OF INNOVATION World Bank (2002)	Knowledge-producing organizations in the education and training system, appropriate macroeconomic and regulatory framework, innovative firms and networks of enterprises, adequate communications infrastructures, and access to the global knowledge base or certain market conditions that favour innovations.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION OECD (2002b)	The performance of an innovation system increasingly depends on the intensity and effectiveness of the interactions between the main actors involved in the generation and diffusion of knowledge.	• Structure-based view (i.e. wholly considered)
NATIONAL SYSTEM OF INNOVATION Edquist (2005)	Importance of studying the activities (causes, determinants) in systems of innovation in a systematic manner. Providing a provisional list of ten activities for innovating firms.	• Activity-based view (i.e. emphasis and list of hints only)
SECTORAL SYSTEM OF INNOVATION Malerba (2002, 2004, 2005)	Identifying the main building blocks (i.e. Knowledge and Technological Domain, actors and networks, and institutions) of a sectoral system of innovation.	• Structure-based view (i.e. wholly considered)
TECHNOLOGICAL SYSTEMS Carlson and Stankiewitz (1995); Hughes (1984); Callon (1992)	Networks of agents in technological systems for the generation, diffusion and utilization of specific technologies.	• Structure-based view (i.e. wholly considered)
TECHNOLOGICAL SYSTEMS Rickne (2000)	A list of eleven functions (activities) for technology-based firms.	• Activity-based view (i.e. wholly considered in non-profound manner)
TECHNOLOGICAL SYSTEMS	A list of five primary functions (activities) for technological systems.	• Activity-based view (i.e. wholly considered in

Johnson and Jacobsson (2003)		non-profound manner)
NATIONAL TECHNOLOGY SYSTEMS Carlo Pietrobelli (2006)	Called for greater attention to the "National Technology System", which places greater emphasis on policies and measures that facilitate access to foreign technologies, and support domestic efforts, especially at the firm level, to master technologies and learn.	• Structure-based view (i.e. wholly considered) • Activity-based view (i.e. emphasis only)
TOTAL INNOVATION MANAGEMENT SYSTEM Xu et al. (2007)	Managing innovation in all organizational sectors, all employees and covers all time and space dimensions (TIM framework).	• Structure-based view (i.e. wholly considered)

Table (2.4): Approach Type of Innovation System

It remains, however, to mention that the convergence of most research literature into structure - based view leaves a gap at innovation process level, limiting the value of research results for innovation systems analysis. Hence, for innovation systems frameworks to be more active, there is an immanent need to develop them in terms of a comprehensive activity-based view (e.g. activities of knowledge creation, diffusion and exploitation in innovation processes) alongside the structure-based view (i.e. actors, interactions, institutional set-up, etc.) rooted in the traditional frameworks.

2.8.4 Inadequacy of Innovation System Approach

Throughout the relevant literature of systems of innovation (Niosi et al., 1993; Gu, 1999; Edquist, 2001; Intarakumnerd et al., 2002; Arocena and Sutz, 2002), it is obvious that, the technological innovation issues in developing countries are quite different from developed countries, and the traditional frameworks of innovation systems, i.e. national systems of innovation and sectoral system innovation, are focused mainly on analysing the innovation processes in developed countries. Therefore, it can be claimed that those traditional frameworks are inadequate alone to address such issues in developing nations as systems of innovation in developed countries dedicated to maintain or improve an already established level of competitiveness and growth, whereas in developing countries the systems of innovation have in essence the task of catching-up in addition to suffering problems of weak competitiveness level (see global competitiveness index published frequently by United Nations).

2.8.5 Research Gap within Absorptive Capacity Interactions

Absorptive Capacity, learning climate and conceptualization capability are regarded among defining features of knowledge-based economy. They are a focus of little interest amongst academics as well as policy makers (see table 2.1, pp.57-60). This weak interest shapes a sort of research gap within absorptive capacity interactions. Important attempts in this thesis would be made to try to elucidate the interactions between these diverse concepts.

The measuring dimensions of technological absorptive capacity in this study are confined to ability of the research community to: 1) Acquire external state-of-the-art technological knowledge, for instance, through know-how licensing, research partnership, etc. 2) Understand and assimilate acquired technological knowledge. 3) Develop new technological knowledge by the use of obtained knowledge.

On the other hand, learning climate in the sector under study is measured in terms of the following dimensions: 1) To what extent learning-supportive elements (e.g., learning mistakes are tolerated, conducting experimentation is encouraged, etc.) are available. 2) To what extent learning-forced elements (e.g., severe competition, massive work duties, research challenges, constructive criticism, high risk, etc.) are existed. 3) To what extent organizations of interest emphasize learning from previous work mistakes and pitfalls. 4) To what extent do training programmes being conducted to research groups gear directly to research activities? 5) To what extent is real development of human resources considered (see Boydell and Pedler, 1981).

Conceptualization capability is therefore well thought-out based on the capability of research team to: 1) Build shared vision about the research problem to be solved. 2) Search and explore possible technological opportunities. 3) Participate in formulating R&D strategy. 4) Originate research and experimental design. 5) Determine and evaluate alternatives to solve research problem.

Chapter Three

ESSENTIALS OF TECHNOLOGY DEVELOPMENT

3. ESSENTIALS OF TECHNOLOGY DEVELOPMENT

3.1 INTRODUCTION

Throughout human history, technology has had a profound impact on human development and on the economic prosperity of countries, industries, and businesses depends upon the effective management of technology. The proper acquisition of technology strongly influences business competitiveness, which is no longer a matter of choice but a matter of survival in many marketplaces.

For the oil industry, technology has played and will continue to play a major role in the success of both; upstream and downstream operations. At the micro-level, operating firms, technology suppliers and associated research laboratories in oil business sector challenge, nowadays more than ever, the demand for developing more petroleum technology in order to solve numerous technical problems arise day-to-day all through oil & gas exploration, production and processing activities; to accomplish future development plans of hydrocarbon projects; and to lessen the scale of business-associated risks. As a result, such kind of technological demand is naturally arisen to cope with augmented energy needs.

The process of technological innovation comprises a set of arduous brainstorming endeavours that consumes a lengthy time to transform ideas and scientific knowledge into physical applications that have socio-economic impacts. The innovation chain equation requires integration of knowledge and expertise to attain the scientific invention; entrepreneurial spirit and supportive environment to commercialize that invention based on recognized market and society needs; and management skills to plan technological strategies, allocate resources and control relevant costs and timing of technology introduction. Hence, such equation is crucial to developing successful technology and entails paying a considerable attention to realize its main components and dimensions.

This chapter aims at building a broad understanding to the key elements of successful petroleum technology development through revealing the approach of technological innovation dynamics at micro-level. The sequence of this chapter starts with demonstrating the concept and evolution of technology management, followed, in section three, by recognizing the main enablers of technological innovation (e.g. characteristics of innovative organization, entrepreneurship, institutional support, technological absorptive capacity, etc.). Technology interrelated implications (e.g. mapping technology environment, formulating technology strategy, technology life cycle, models of technological innovation, dynamics of diffusion, etc.) are essentially highlighted in section four. Technological innovation output dimensions that affect the performance of industry and overall society will be articulated in section five, and the last section will be dedicated to overall concluding remarks.

3.2 TECHNOLOGY MANAGEMENT: CONCEPT AND EVOLUTION

Over the last decades management of technology (MOT) has progressively recognized as an academic discipline. Drejer (1997) identifies four schools of thought as the discipline evolved from R&D management, through innovation management and technology planning before developing the strategic management of technology (SMOT). Under this taxonomy, MOT is divergent from economics and public policy and is firmly located within the engineering management field.

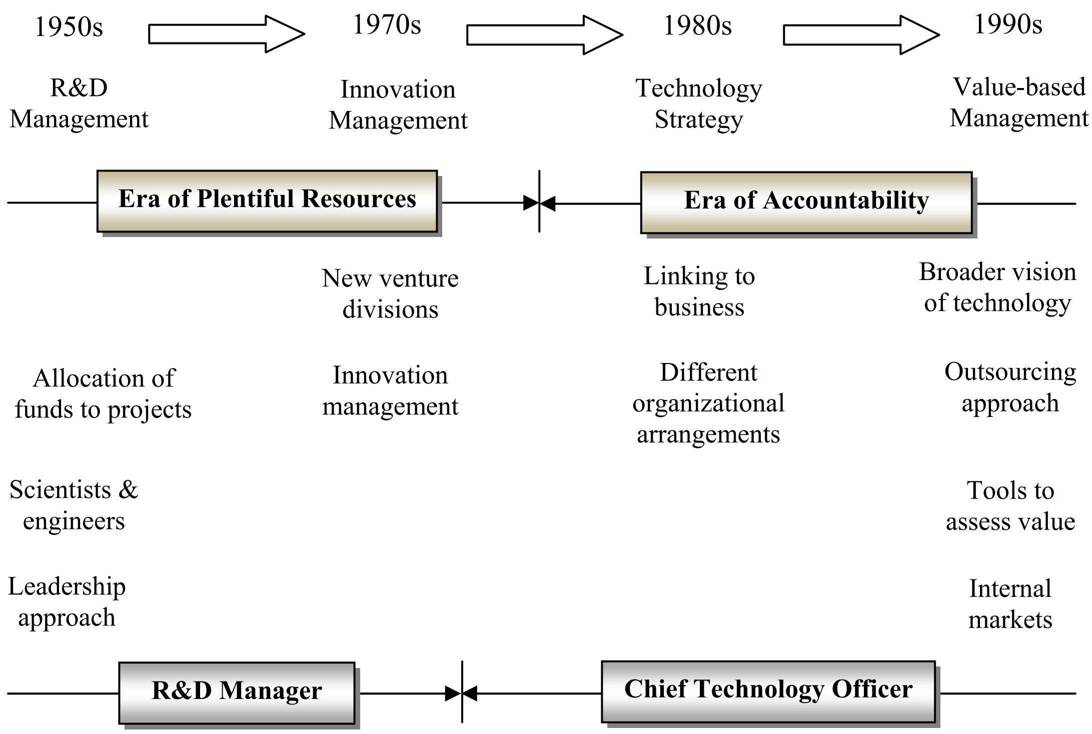
Brockhoff (2003) plots the roots of MOT back to the philosophical writings of Francis Bacon's 17th century ideas concerning the organization of inquiry and also discusses the significance of the engineering perspective and its associated investigations which followed the establishment of industrial research and development laboratories about a century ago. Brockhoff continues by discussing the influence of the Schumpeterian view of the innovator as entrepreneur (see Solow, 1957), which represents a perspective often viewed as a contribution from management planning (Teichert and Pilkington, 2006).

In 1987, the U.S. national research council defined management of technology as:

> *"Management of technology links engineering, science and management disciplines to plan, to develop, and to implement technological capabilities to shape and accomplish the strategic and operational goals of an organization" (Narayanan, 2001, p.8).*

For simplicity, the management of technology can be redefined as the principles of strategy and organization involved in technology choices, guided by the purpose of creating value for both investors and users. In this sense, Omachonu and Khalil (1988) highlighted that the management of technology in developing countries can be experienced in order to: 1) Facilitate the assessment and upgrading of traditional technologies. 2) Support the effective acquisition, absorption and adaptation of foreign-owned technology. 3) Enhance the development of innovative processes and techniques as well as the fulfilment of further development goals. 4) Provide adequate employment opportunities and fulfilment of basic socio-economic needs.

Narayanan (2001) indicates that the beginnings of management of technology can be traced back to the 1950s, when R&D management ideas were developed, this was a period characterised by plentiful resources to R&D. During the 1960s and 1970s, there was interest in understanding innovation. In the last quarter of the twentieth century, the impact of global competition was keenly felt, and consequently, renewed attention to technology was paid. The current management of technology reflect the altered views on technology in light of the new realities. Figure 3.1 shows a bird's eye view of this evolution.



Source: Adapted from Narayanan (2001)

Figure (3.1): Evolution of Technology Management

3.3 MAIN ENABLERS OF TECHNOLOGICAL INNOVATION

The term innovation has its origin in the Latin word "*innovare*" which means to renew, to make new, or to change. Innovation has its definition by many scholars; Joseph Schumpeter in 1930s defined innovation as "*new combination of existing resources*", and labelled this combinatory activity "*the entrepreneurial function*".

In its Oslo manual, OECD (2005a) defined the innovation more broadly as;

> *"Innovation is the implementation of a new or significantly improved product (good or service), or process; a new marketing method; or a new organizational method in business practices, workplace organisation or external relations" (p.46).*

Whilst, Narayanan (2001) argues that;

> *"Innovation refers both to the output and the process of arriving at a technologically feasible solution to a problem triggered by a technological opportunity or customer need "(p.68).*

Thus, innovation involves the creation of a product, services, or process that is new to an organization. Innovation is the introduction into the marketplace, either by utilization or by commercialization. An innovation may be a change in industrial practice, which improves productivity (Kalil, 2000).

Creation of technology in the upstream and downstream of oil industry may take place in terms of new or improved products (i.e. material, device, component, sophisticated software package, etc.), and new or improved processes (i.e. exploration technique, drilling method, well logging technique, specific technique for oil & gas production, particular process of petrochemical manufacturing, dehydration method, distillation system, EOR technique, reformulated fuel process, etc.). Bright (1969) indicated that technological innovation includes the initiation of the technical ideas, the acquisition of the necessary knowledge, its transformation into usable hardware or procedure, its introduction into society, and its diffusion and adoption to the point where its impact is significant.

However, firms in any business field can innovate mainly in response to some enablers counting internal and external factors.

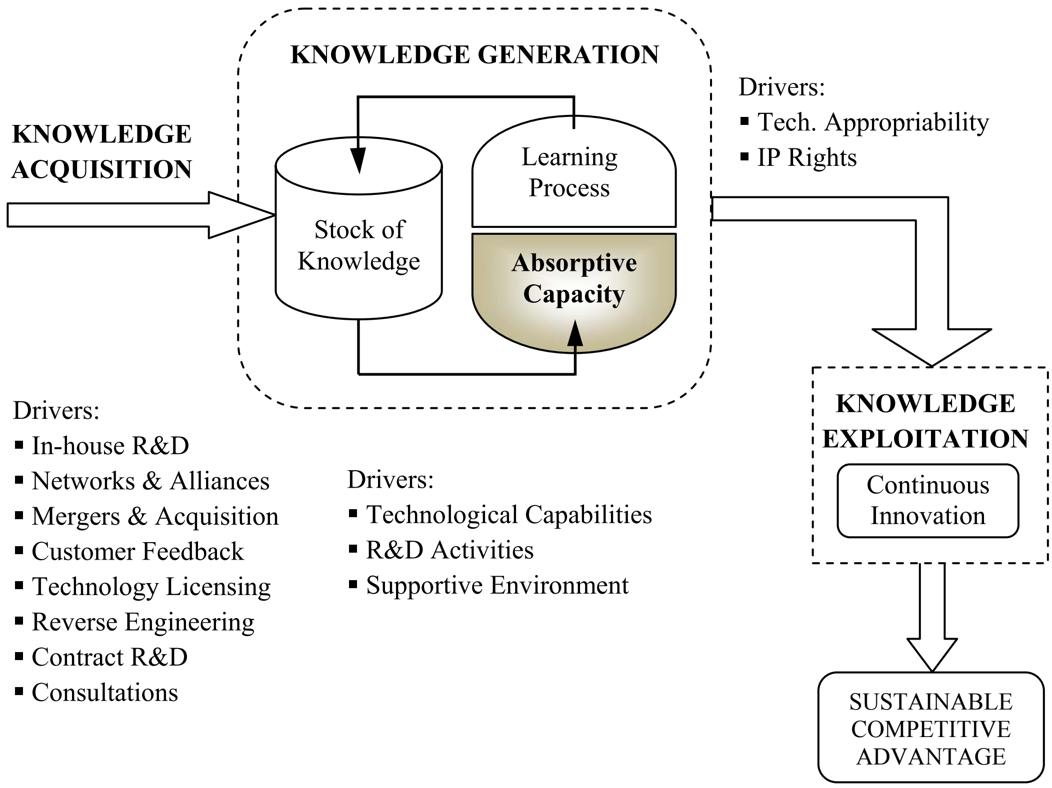
3.3.1 Internal Enablers

The recognized enablers to innovation inside the firm encompasses, namely;

– *Characteristics of innovative organization*: The proper management of technology requires organizations capable of fostering innovation and ensuring the effective use of technological assets. In the current environment of increased dependence on technology, organizations must be able to take advantage of technological progress for their competitive advantage. Tidd et al.(2005) argue that the innovative organization can be built through: 1) Shared vision leadership and the will to innovate; 2) Appropriate organization structure to cope with the speed and rate of technological change; 3) Key individuals to innovate; 4) Stretching training and development internally; 5) High involvement in innovation for sustainable competitive advantage; 6) Effective team working; 7) Creative climate; 8) External focus on rivals; 9) Extensive communication and networking; 10) Building learning organization; and 11) Enhancing organizational innovation.

In addition, Narayanan (2001) identified five cultural traits of innovative organizations, namely: 1) Enthusiasm for knowledge by considering encouragement for accumulation of knowledge is a legitimate undertaking; 2) Drive to stay ahead in knowledge which means staying knowledgeable about the latest developments in technology; 3) Tight coupling of complimentary skill sets which refers to simultaneous attention to both developing deep reservoirs of knowledge and skill in special capabilities and having a plan to diminish the boundaries between disciplines; 4) Alteration in activities which reflects the comprehension of the fact that activities are never completely perfect; and 5) Higher order teaming to continual self-examination to discover insights within one activity that may be transferred to other activities within the firm.

– *Technological absorptive capacity*: Continuous innovative activities lead to a sustainable competitive advantage necessary to ensure survival for organizations. Firms being aware of this, try hard to generate technological knowledge vital for developing new or improved products and processes. In this regard, an organization's absorptive capacity, which largely depends on the absorptive capacities of its individuals, plays a central role in generating such technological knowledge and considered consequently an internal enabling factor to innovation. Cohen and Levinthal (1990) refer absorptive capacity to *"the ability of firm to assimilate and reproduce new knowledge gained from external sources"*. Firms that have absorptive capacity are capable to utilize knowledge obtained externally to promote their research activities. Further, without this capacity, firms could become "*locked out*" in their ability to assimilate the technology at a later time. Therefore, a company's absorptive capacity is a dynamic capability that influences the nature and sustainability of that company's competitive advantage (Zahra and George, 2002). The development of an organization's absorptive capacity can be built on prior investment in the development of its personnel absorptive capacities through: 1) Building learning capacities which involves the development of the capacity to assimilate existing knowledge, 2) Enhancing problem solving skills which represent a capacity to create new knowledge, and 3) Investing directly in absorptive capacity by advanced technical training. Figure 3.2 demonstrates the central role of absorptive capacity in generating technological knowledge.



Source: Adapted from Davenport, et al. (2003)

Figure (3.2): Absorptive Capacity Central to Knowledge Generation

– *Research and development*: Academicians and industrialists have traditionally recognized R&D as the management of scientific research and the development of new products. Roussel et al. (1991) defined the concept of R&D as: "*To develop new knowledge and apply scientific or engineering knowledge to connect the knowledge in one field to that in other*". This definition reflects the more recent view that scientific knowledge is expanding so rapidly that it is extremely difficult for one company to remain a breast of all the technologies that it needs for its products (Trott, 2008). Thus, the general objectives of corporate R&D are to: 1) Have a window on science for long-term threats and opportunities. 2) Maintain existing businesses. 3) Create the technology base for new businesses (Betz, 2003).

The research and development plays a central role in the process of technological innovation. This process coverts knowledge into useful products and services and requires the integration of R&D and existing technologies to bring innovations to the customer. Khalil (2000) suggests eight stages that outline the process of technological innovation as follows: 1) *Basic research*: This is research for the sake of increasing the general understanding of the laws of nature. It is a process of generating knowledge over a long period of time. It may or may not result in specific application. 2) *Applied research*: This is research directed toward solving one or more of society's problems. Basic and applied research advance science by systematically building knowledge on previous knowledge. Successful applied research results in technology development and implementation. 3) *Technology development*: This is a human activity that converts knowledge and ideas into physical hardware, software, and services. It may involve demonstrating the feasibility of an idea, verifying a design concept, or building and testing a prototype. 4) *Technology implementation*: This is the set of activities associated with introduction a product into the marketplace. Technology implementation involves the first operational use of an idea or a product by society. It entails the activities associated with ensuring the successful commercial introduction of the product or service, such as cost, safety, and environmental considerations. 5) *Production*: This is the set of activities associated with the widespread conversion of design concepts or ideas into products and services. Production involves manufacturing, production control, logistics, and distribution. 6) *Marketing*: This is the set of activities that ensures that consumers embrace the technology. It entails market assessment, distribution strategy, promotion, and the gauging of consumer's behaviour. 7) *Proliferation*: This is the strategy and associated activities that ensure the widespread use of the technology and its dominance in the marketplace. Proliferation depends on methods of exploiting the technology and on the practice used for marketing the technology. For example, Microsoft spreads the use of its Internet browser technology by including the browser with its popular Window software. 8) *Technology enhancement*: This is the set of activities associated with maintaining a competitive edge for the technology. It entails improving the technology, developing new generation or new applications for the technology, improving quality, reducing cost, and meeting customer's special needs. Technology enhancement increases the life cycle of the technology.

The management of research and development needs to be fully integrated with the strategic management process of the business. This will enhance and support the products that marketing and sales offer and provide the company with a technical body of knowledge that can be used for future development. The R&D function has also to make some assessment of the future in order to perform effectively as predicting the future is extremely difficult and there are many factors to consider: economic, social, political, technological, natural disasters, etc. Thus, senior R&D mangers should build into their planning process a conscious view of the future that includes: environmental forecasts, comparative technological cost-effectiveness, risk, and capability analysis (Trott, 2008).

Roussel et al. (1991) classified the R&D into three categories expressed in business terms as follows: 1) Incremental R&D: Small "r" and big "D". The goal is small advances in technology, typically based on an established foundation of scientific and engineering knowledge. 2) Radical R&D: large "R" and often large "D". Progress towards the goal involves elements of discovery. The radical R&D draws on a foundation of existing scientific and engineering knowledge that is insufficient alone to arrive at the developed needs. 3) Fundamental R&D: Large "R" and no "D". The goal is to reach the unrevealed scientific facts.

Table 3.1 (p.99) demonstrates typical characteristics of the three types of R&D.

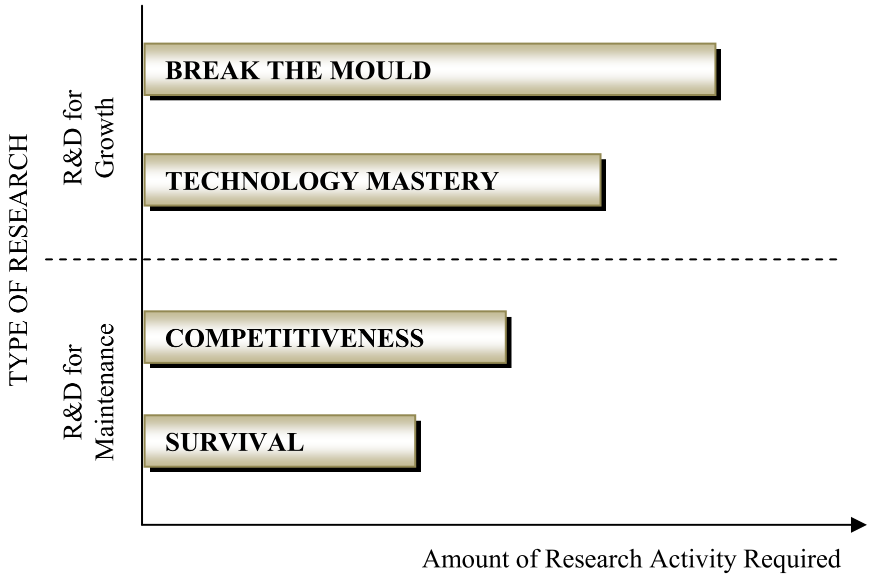
Type of R&D	Probability of Technical Success	Time to Completion	Competitive Potential	Durability of Gained Competitive Advantage
Incremental	V. high, typically 40% - 80%	Short, typically 6-24 months	Modest, but necessary	Short, typically imitable by competitors
Radical	In early stages modest, typically 20% - 40%	Mid-term, typically 2-7 years	Large	Long, often protectable by patents
Fundamental	In early stages difficult to assess; depends on R&D concept	Long, typically 4-10 or more years	Large	Long, often protectable by patents

Source: Roussel et al. (1991)

Table (3.1): Typical Characteristics of R&D Categories

The state of a business in terms of its markets, products and capabilities will largely shape the amount of research effort to be undertaken. Scholefield (1993), as cited in Trott (2008), suggests that there are two forms of activity for a R&D function; growth and maintenance. These two categories are subdivided into four groups as follows: 1) *Survival*: This type of activity is conducted if the decision has been made to exit the business. The role of R&D function in such circumstances is to ensure its interim survival against technological mishaps to process or product. This would be a reactive problem-solving role. 2) *Competitive*: The role of research in such case is to maintain the relative competitive technological position by making improvements to both products and process. 3) *Technology mastery*: This will clearly involve a level of research activity greater than the competitive position in order to keeping abreast of all technological developments that may affect the business's products or processes. This entails more R&D expenditure. 4) *Break the mould*: If the aim is to create a technological advantage then a much higher order of novelty and creativity is required. Following such a strategy will involve developing new patentable technology and may involve a higher level of basic research.

Figure 3.3 (p.100) classifies the level of research using technology leverage.



Source: Trott (2008)

Figure (3.3): The Level of Research vs. Technology Leverage

– *Entrepreneurship spirit*: Technological progress is frequently sparked by entrepreneurs and their entrepreneurial spirit. Bill Gates of Microsoft is one of many examples of successful entrepreneurs. Entrepreneurs are a special breed of people who have the ability to sell or market ideas to others. They possess a particular set of qualities, including vision, courage, initiative, commitment, persistence, independent thinking, drive to succeed, and ambition. Most of entrepreneurs have an appreciation for a particular technology branch, good motivational skills, and a commending personality. They tend to deviate from mainstream thinking, enjoy being the centre of attention, and savour recognition. They could be compulsive in seeking their goals or perfection. Entrepreneurs are not necessarily inventors. Their skill usually lies in bringing innovation to marketplace (Khalil, 2000). Besides, Schon (1967) indicates that it has long been recognized that one of the most important characteristics of a successful technology-based firm is an entrepreneurship culture.

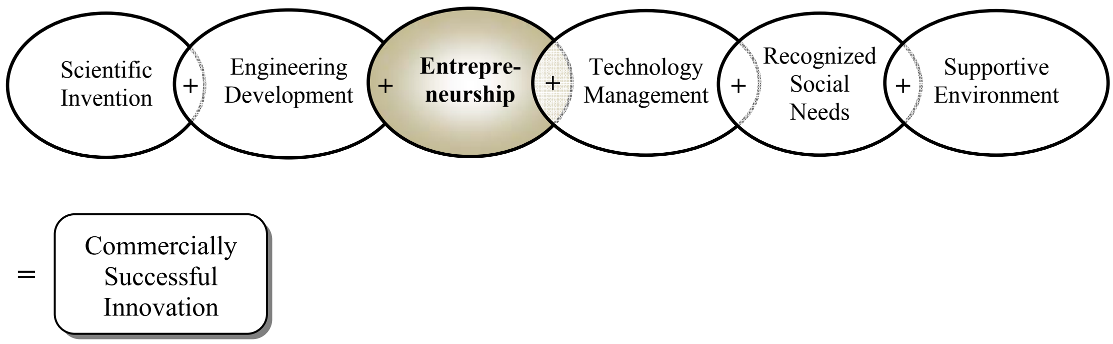
However, one can define accordingly the entrepreneurship as "*the activities that bring together the technical and commercial worlds in a profitable way to make innovation possible*". Thus, entrepreneurship spirit inside the company is a key driving force for innovation and creating technology. Table 3.2 (p.101) exhibits a summary of personal characteristics of entrepreneur and professional manager.

ENTREPRENEUR	PROFESSIONAL MANAGER
Self-starter; defines goals as he/she goes alone.	Career-oriented with well-defined goals.
Does the important things by himself/herself.	Accomplishes tasks through people.
Not a good delegator; strong need to control.	A good delegator and motivator.
Charismatic leader, but hard to follow.	Good leader and people person.
Extremely strong drive and capacity to work.	Competitive and politically astute.
Excellent problem-solving abilities.	Experience, ability, and accomplishments are evident.
Innovative thinker. Realistic; takes moderate and well-calculated risks.	Plays by the rules, not a risk taker.
Committed to the company.	Committed to self more than to company

Source: Paradi (1994)

Table (3.2): Personal Characteristics of Managers

Martin (1984) has developed a chain equation to explain the sequence of innovation process. In this chain, entrepreneurship plays a central role among others to creating a commercially successful innovation. Figure 3.4 illustrates the main functions of Martin's chain of innovation.



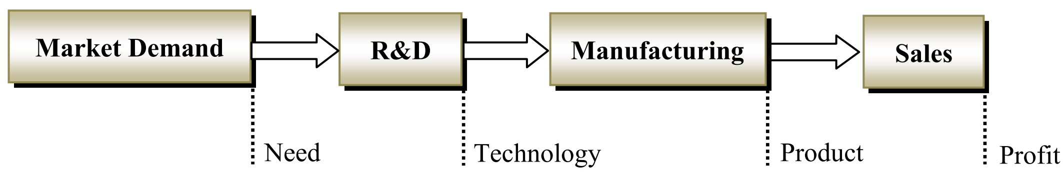
Source: Adapted from Martin (1984)

Figure (3.4): Chain Equation of Successful Innovation

3.3.2 External Enablers

The external factors that corroborate firms to innovate are essentially coming from the adjacent environment, they can be articulated as:

– *Market demand:* Technological development is spurred by market pull, i.e. technology often developed based on market demand. From 60 to 80 percent of important innovations in a large number of fields have been in response to market demands (see Utterback, 1974; Von-Hippel, 1977). This led to the second generation of innovation model the so-called "*Demand-pull*" model of innovation (i.e. linear model) which states that; the market signals need for something new (i.e. demand pull) which then draw the new solution to the problem (i.e. research output). In this sense, the necessity becomes the mother of invention. Figure 3.5 depicts the sequence of demand-pull innovation model.

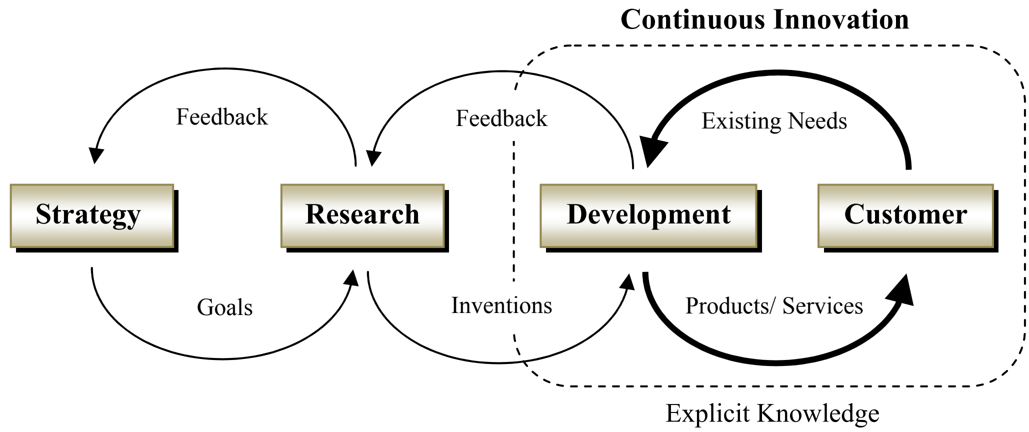


Source: Adapted from Trott (2005)

Figure (3.5): Demand-Pull Innovation Model

Typically, in many organizations, communication about market need quite often seems to be initiated by someone other than the person who generates the idea for an innovation. Such communication may come from users, outside consultants hired by a firm, or individuals who serve in consulting roles and have wide diversity in work assignments. Alternatively, these ideas could emerge from the frequent interaction between users and innovating firms. These sources of ideas have been observed in the case of both product technologies (e.g. gas chromatography, electronic microscope) as well as in process innovations in the petroleum industry, and the chemical industry (Narayanan, 2001).

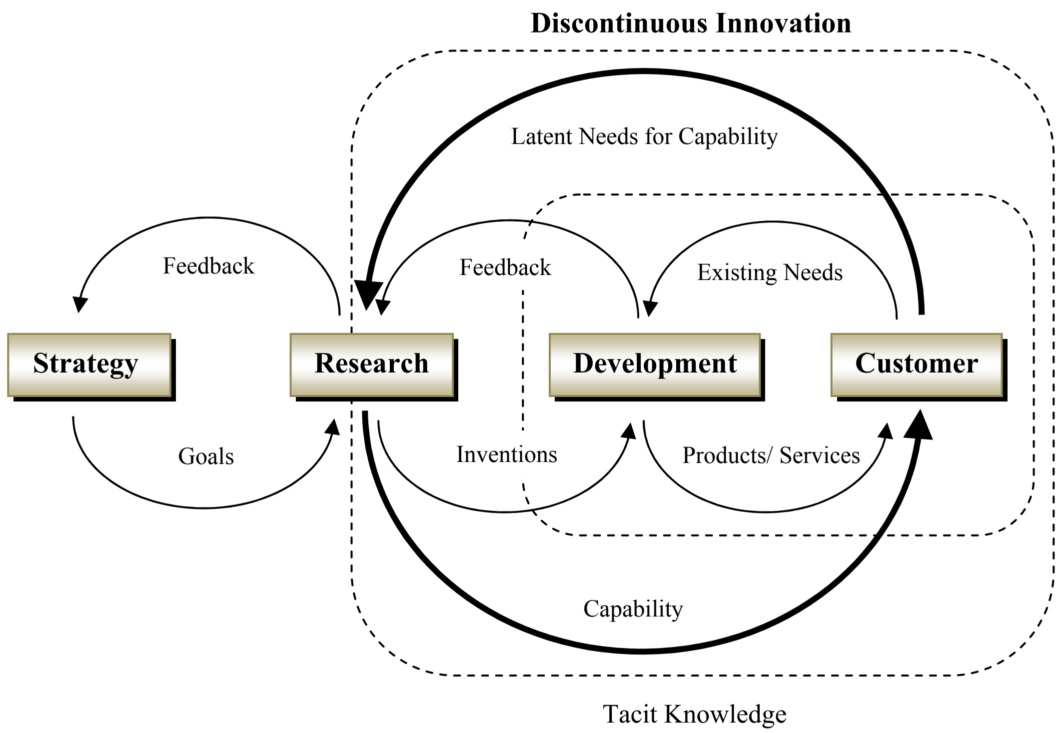
Miller and Morris (1999) distinguished between market research for continuous and discontinuous innovations. They argued that traditional market research is limited to identifying the explicit level of existing knowledge, existing needs, existing products, and existing services through use of dialogue and questionnaires. Fulfilling these needs is done through continuous innovation in the product development process as depicted in figure 3.6.



Source: Miller & Morris (1999)

Figure (3.6): Market Research for Continuous Innovation

Whilst, marketing for discontinuous innovation shifts from identifying and satisfying existing needs for products and services to identifying and satisfying latent needs for new capability. This puts the research activity in direct communication with customers in a process of mutually dependent learning that supports discontinuous innovation as shown in figure 3.7.



Source: Miller & Morris (1999)

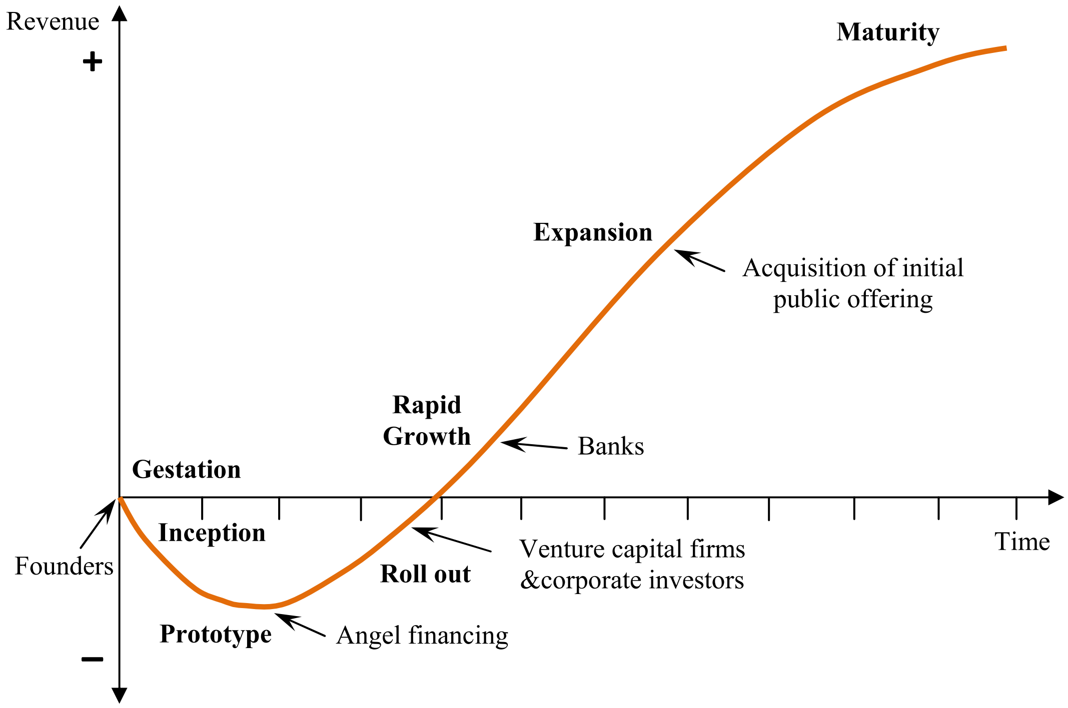
Figure (3.7): Market Research for Discontinuous Innovation

– *Competitiveness:* In the last decades, competitiveness has increasingly emerged as a buzzword used to describe the technical and economic position of a particular firm with respect to its rivals in a specific marketplace. It is the process by which one entity (i.e. a person, an organization, or a state) strives to surpass another. For a firm, being competitive means providing timely and in cost-effective manner products or services to meet more efficiently than others the customer satisfaction and the market demand. In addition, several factors must exist to remain firms competitive such as the ability to compete, the desire to succeed, the availability of key resources, and commitment. At the firm level, management of technology is important not only to increase profit but for survival. Companies that are unable to harness and optimally utilize technology will lag and may not survive any more in a severe competitive environment. To become or stay competitive, companies must be able to:1) Develop a culture in which the value of technology as a strategic competitive weapon is fully appreciated, 2) Understand the dynamics of the technological innovation process, 3) Monitor and forecast technological change, 4) Develop and adopt effective methodologies to measure the impact of emerging technologies on their business, 5) Facilitate and implementation of new technologies in their operations and build the infrastructure necessary for migration from one technology to another, 6) Prepare, train, and hire the proper workforce to implement the new technology, 7) Develop an organizational structure that permits effective and efficient implementation of technological change, and 8) Develop an appropriate reward system for employees and managers (Khalil, 2000).

Hence, growing competitive pressure imposed by rivals and peers is another external enabling force to keep firms producing technological innovation towards achieving sustainable competitive advantages necessary to their continued existence since business organizations in the recent global competition era must innovate or die and their ability to learn and adapt to change becomes a core competency for survival.

– *Institutional set-up*: The successful adaptation and integration of technological development at firm level requires a well-designed institutional framework at a national or industry level (e.g. Libyan oil sector). Such framework encompasses rules, laws, regulatory acts, and polices which support creating a right environment to innovation and technology investment. For instance, the government can create the right environment through: 1) enacting institutions that improving the "*Triple-Helix*" collaboration (university–industry–government); increasing government's fund for R&D and maintaining the basic research; 2) stimulating openness to foreign trade and foreign direct investment (FDI); 3) facilitating the development of deep and sound financial markets and flexible labour markets; 4) applying effective competition polices; and 5) establishing robust "*appropriability*" regimes (e.g. IPR regime). Only in such environment firms are willing and capable to engage in acquisition, adaptation, and creation of new technologies and in recruiting high skills, establishing alliances, and performing in sustainable development programmes (see UNIDO, 2005).

– *Venture capital (VC)*: It is a long term equity capital invested in new or rapidly expanding enterprises. It is the lifeblood of entrepreneurs. Traditional debt financing is not always available to "*start-up*s" and other emerging enterprises because they generally lack the collateral, track record, or earnings required to getting a loan. Most entrepreneurs seek initial "*seed*" capital from family members or wealthy individual investors, often referred to as "*business angels*," who are willing to take the risk associated with start-ups. This informal venture capital community finances the vast majority of new enterprises and plays an invaluable role in the entrepreneurial process. The most visible venture capital money comes from professionally managed venture capital firms. These firms are funded by an informal network of investors that include: pension funds, insurance companies, endowment funds, foundations, bank holding companies and their affiliates, corporations, wealthy individuals, foreign investors and the venture capital professionals. Venture capital professionals in this respect are the primary agents between capital sources and new enterprises. They are essentially managers of risk. They assess hundreds of business plans each time and invest in the most promising ventures, and then become actively involved as strategic managers. They invest a combination of equity and expertise in several different ventures; usually in cooperation with other firms; to diversify the risk associated with venture investing. The returns realized by the venture capital process have attracted funds from institutional investors, and as a result the resources available to young growth companies have expanded significantly. Figure 3.8 (p.106) illustrates sources of funds for ventures.



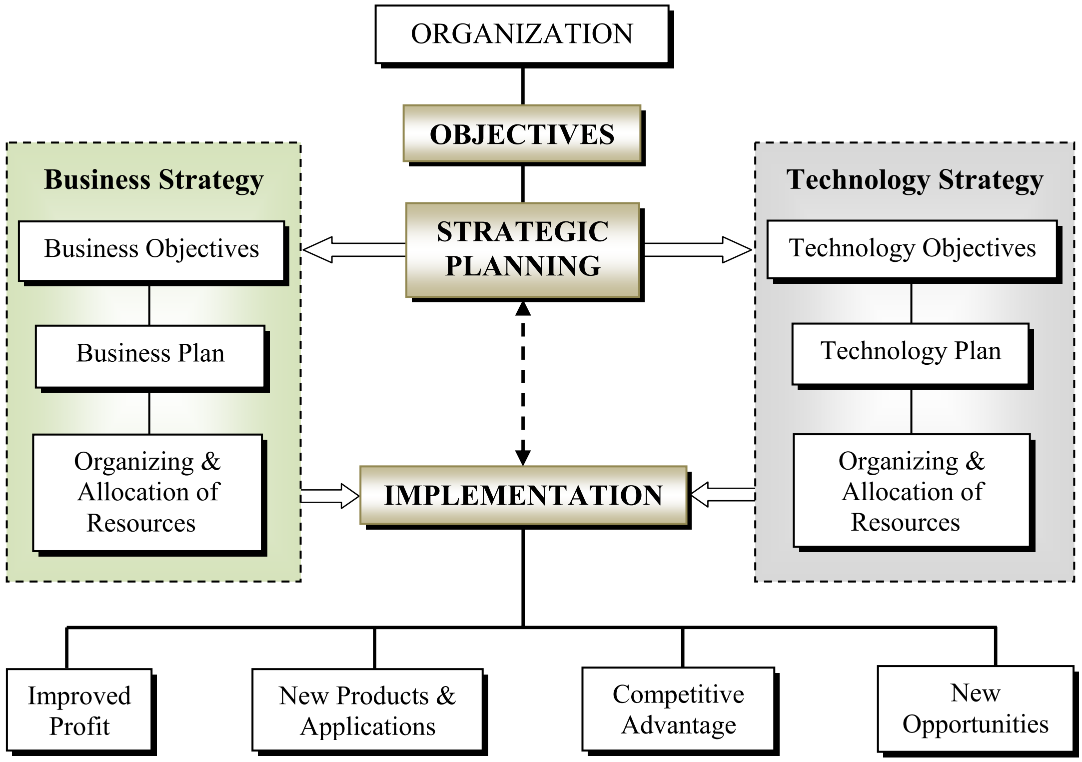
Source: http://www.1000ventures.com/venture_financing

Figure (3.8): Venture Financing: Sources of Funds for High Growth Firms

3.4 IMPLICATIONS OF TECHNOLOGY DEVELOPMENT

3.4.1 Formulation of Technology Strategy

Strategy in generic concept involves envisioning and planning for the future. It is the means by which long-term objectives will be achieved. In business terms, it represents a broad formula of how an organization intends to succeed. A strategy entails defining goals, deciding the way to reach these goals, setting action plans to execute specific tasks, and following up on accomplishments to ensure that objectives have been met (Khalil, 2000). In any technology-based organization, two intertwined strategies should be closely integrated; business strategy which is to attain a sustainable economic advantage (e.g. high profit, large market share, product-long incumbency, etc.) and technology strategy which is to gain a sustainable technological advantage that provides a competitive position. Figure 3.9 (p.107) shows such kind of integration.

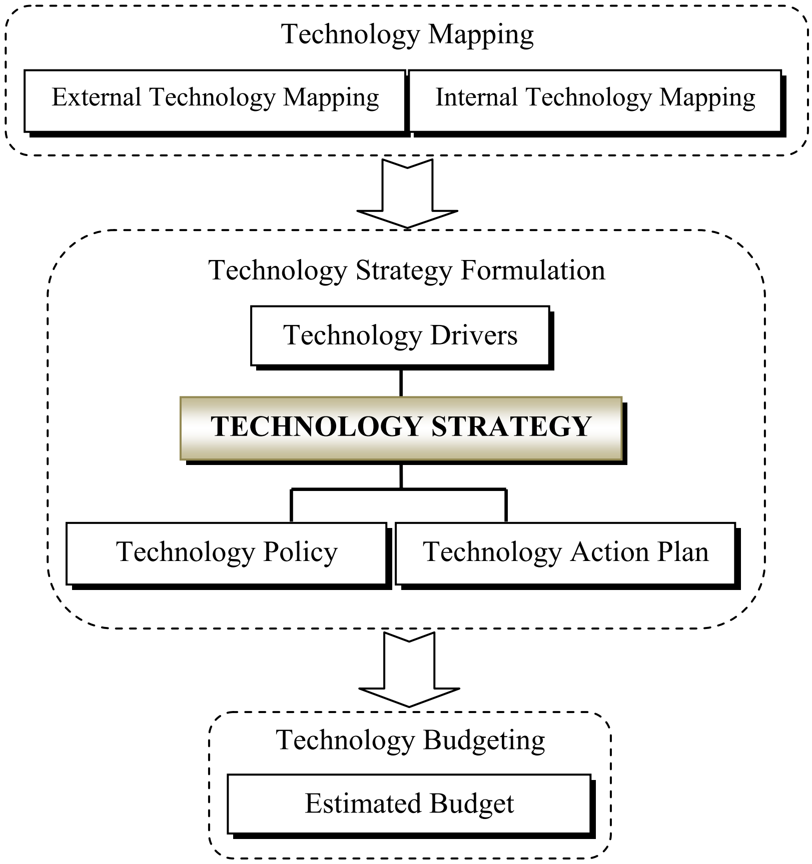


Source: Adapted from Bhalla (1987)

Figure (3.9): Integrated Technology-Business Plan Model

For particular organization, technology strategy formulation starts with technology mapping which comprises:1) *External mapping of technology environment* which is aimed at anticipating technology trends (e.g. competitor's new emerging technologies); determining potential opportunities for technology investment that organization may obtain either through market demand (e.g. owing to competitor incapability to meet such demand) or through organization technology push based on its outstanding technology advantage; and identifying possible organization challenges which may originate from rival threats and from inevitable support to the organization's competitive advantage. 2) *Technology internal mapping* which encompasses; determining strengths and weaknesses of the organization's technological competencies to cope with target opportunities and challenges; and identifying the organization's existing and long-term technology gap relating to its rivals. Besides, management research reveals that firms used to scan their external environment are more likely to be innovative than those that pay attention mainly to their core competencies as means to generate new technologies (Rosenkopf and

Nerkar, 2001). In this context, figure 3.10 demonstrates an adapted framework for technology strategy that can be used at micro-level to formulate technology strategy.



Source: Adapted from Wheelen and Hunger (2008); Narayanan (2001)

Figure (3.10): Technology Strategy Framework

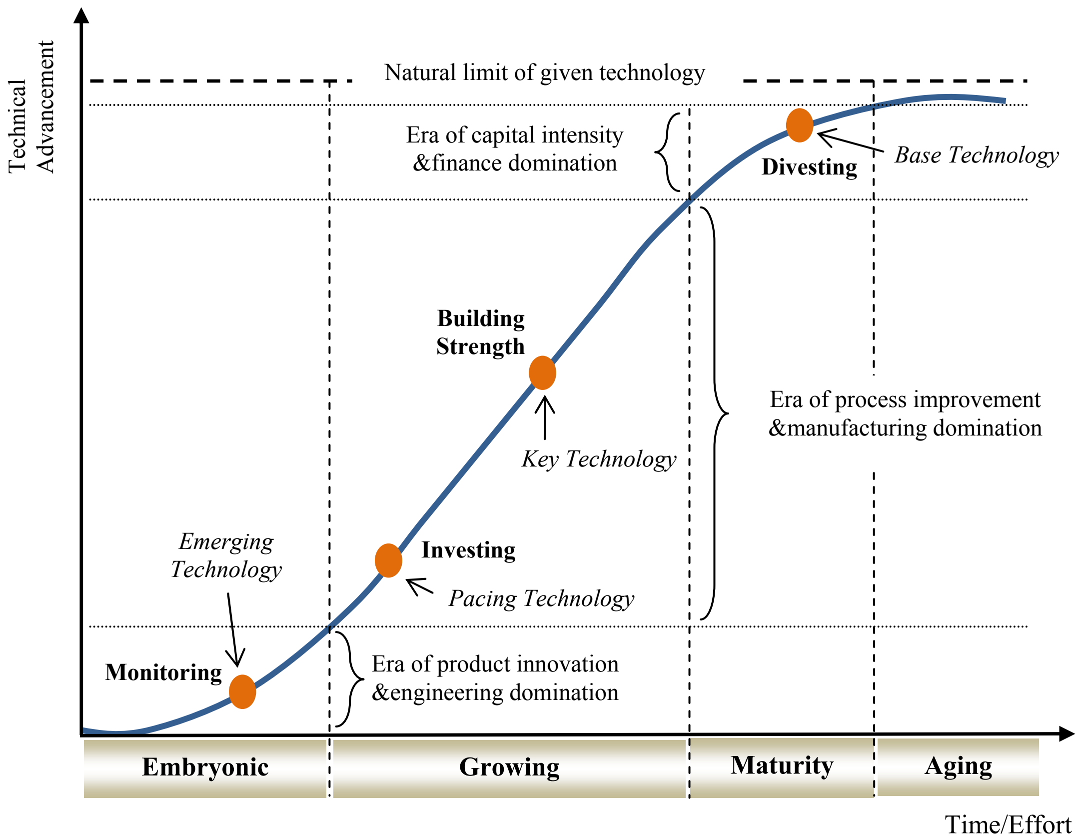
Maidiquie and Patch (1988) define some dimensions of technology strategy, namely: 1) *Technology choices*: Following the technology mapping phase, a firm must decide on the set of technologies to be appropriated, deployed in products that determine its product platforms and deployed in value chains that determine its process platforms, marketed, or simply abandoned. White and Graham (1978) went on to suggest that any new technology has four determinants that must be considered when evaluating its potential for success. They are; *inventive merit* (i.e. a concept that lifts/adds constraints on the existing technology), *embodiment merit* (i.e. additions to the basic invention that result in enhancement of the core product. For example, the new technology may become even more effective when combined with other technology or with better scheduling methods), *operational merit* (i.e. the effect of new technological innovation either positive or negative on a company's existing business practices and operations), and *market merit* (i.e. how strongly the customer will accept the new innovations over what is currently available). 2) *Desired level of competence*: In this regard, technological leadership or followership should be decided. Technological leadership refers to opportunities where the firm attempt to be first to introduce product, process, or management technologies, whilst technological followership, on the other hand, applies to firms who adopt already proved technologies or who decided not to adopt any particular new technology at all. Porter (1985) describes three factors that must be considered when deciding whether or not to pursue a technological leadership strategy; *the degree to which a firm can sustain its technological lead over the competition*, *the advantages of being the first to adopt a new technology*, and *the disadvantages of being the first.* 3) *Technology acquisition*: Two basic alternatives are available to a firm; develop the technology internally, or purchase it from an external source. Many reasons for internal development or external acquisition of technology are closely related to the advantages and disadvantages of following a technological leadership strategy. In general, a firm that is following a leadership strategy would tend to spend more on R&D because the company's ability to produce innovations is closely related (although not entirely determined by) to the amount it spends on R&D. In other words, a leadership strategy tends to be based on a "*proactive*" approach to R&D, whereas a followership strategy involves a "*reactive*" approach. While this may be the case, it does not mean that leaders ignore the option of purchasing technologies externally, In fact, it may be necessary for the leaders to explore other means of obtaining technologies in order to maintain their leadership position (Noori, 1990).

3.4.2 Technology Planning

Technology planning is a key element of business planning. It is largely needed at micro level to provide the market with value-based technologies. Hamel (1996) differentiates between strategizing and planning. Strategizing is creative and revolutionary work, while planning is systematic action and follows established methodologies. Strategy determines the formula by which firm intends to succeed.

Planning charts the procedures and actions to be followed. Planning is essential for successful strategy implementation and valuation.

The key step in technology planning is "*forecasting*", which explores the future to guide the present. Firms who perform well forecasting can seize technological opportunities timely and as a result harvest the rewards of future changes. Technology life cycle model or the so-called "*S-curve*" as depicted in figure 3.11 is a useful tool in forecasting, where understanding the maturation of a given technology is important for detecting the signals of potential technological change or "*discontinuity*" which, in turn, leads to emergence of new technology. In other words, when a technology reaches its natural limits it become a mature technology vulnerable to submission or obsolescence by a "*Creative Destruction*".



Source: Adapted from Steele (1989) and Khalil (2000)

Figure (3.11): Technology Lifecycle Model

Firms' investment in a particular technology is decided according to the position of that technology on the S-curve. If the technology is in the "*embryonic*" phase but has not yet demonstrated potential technological change which could affect future competition basis, it is considered an "*emerging technology*", and firms interested in this technology field should monitor such emerging technology. If the technology is further along the curve of progress and has demonstrated its potential for changing the competition basis, it is deemed a "*pacing technology*". Firms interested in being players in the technology arena should consider investing selectively in pacing technologies. The technology which has a strong impact on the value-added stream of performance, cost and quality is called "*key technology*". It allows a firm to develop a proprietary position in products or processes. Key technologies are essential to the success of firms. They influence the growth phase of the technology S-curve, and they have a major impact on a firm's competitive position. Firms should be prepared to increase their strengths systematically in key technologies. As technologies mature, they become known as "*base technologies*" which are necessary for participation in business, but they provide a firm with little or no competitive advantage. Base technologies are considered commodities usually available to all competitors. When a technology reaches this stage of the technology life cycle, companies should start divesting selectively while reaping the benefits from the mature technology. In the aging stage of technology, a firm must have already developed its strategic options; otherwise, it will suffer the consequences of going out of business (Khalil, 2000).

The general characteristics of technology maturity are summarized in table 3.3.

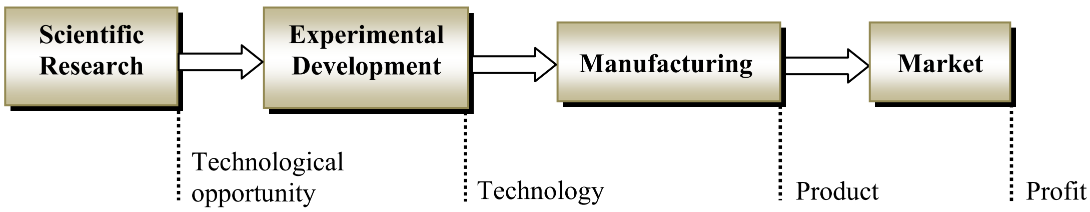
Technological Maturity	**Time to Market** (Year)	**Knowledge of Competitive R&D**	**PREDICTABILITY**			**Durability of Commercial Advantage**
			Technical	**Reward**	**R&D Costs**	
Embryonic	7-15	Poor	Poor	Fair	Poor	High
Growth	2-7	Fair-Moderate	Fair	High	Moderate	Moderate
Mature	1-4	High	High	High	High	Fair
Aging	1-4	High	V. High	V. High	V. High	Short

Source: Roussel (1984) as cited in Roussel et al. (1991)

Table (3.3): Generalized Characteristics of Technology Maturity

3.4.3 Models of Technological Innovation

Understanding of innovation as a process characterizes the patterns or models that can be utilized to manage such process. Early models considered innovation as a linear sequential process, either through "*Technology-push*" model which considers the technological opportunity arising out of research activities is the source for technology development, and the market is only a recipient of R&D fruits as seen in figure 3.12; or through "*Demand-pull*" model in which technology is developed to meet a market demand which is, in turn, stimulated by customers need; and the market is the source for directing R&D which has consequently a reactive role (see figure 3.5, p.102).

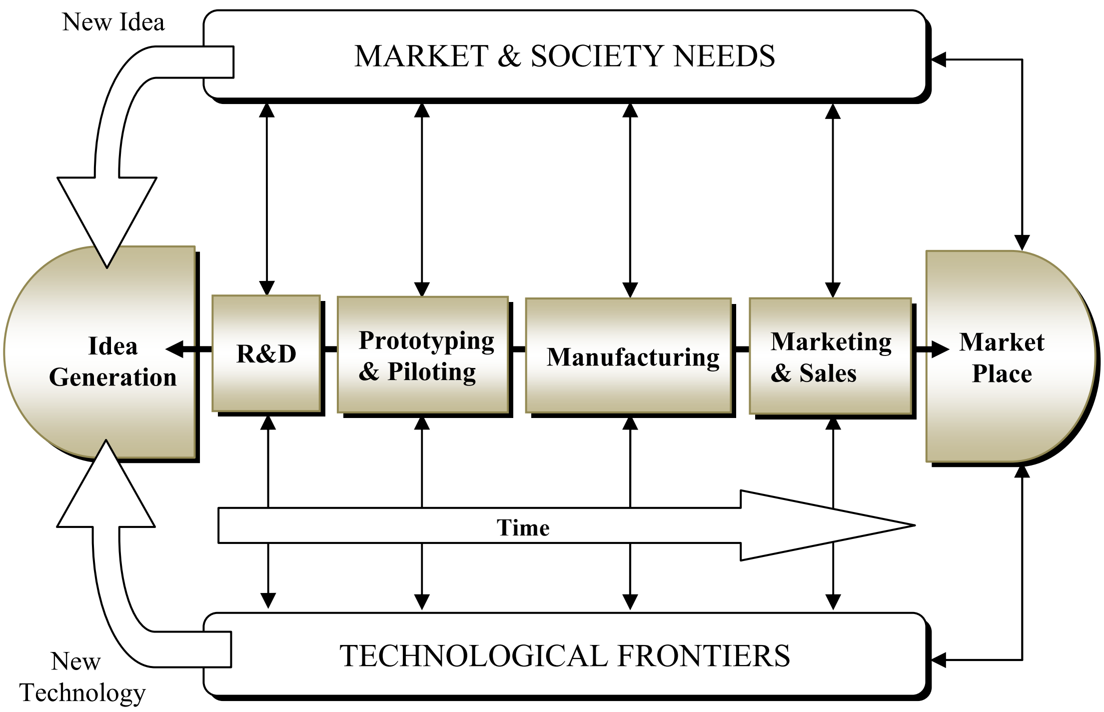


Source: Based on Rothwell (1992) and Tidd et al. (2005)

Figure (3.12): Technology-Push Innovation Model

The limitations of linear sequential models are clear, because in practice innovation, which is a coupling and matching process, the interaction is a critical element (Freeman, 1982; Coombs et al., 1985). Successful innovation requires interaction between the two preceding models. Such necessity of interaction has bred the third model of technological innovation which labelled "*Integrative Model*" of innovation. This model is a combination of both the technology-push and demand-pull models of innovation. It involves the consolidation of market need and new technology capabilities. In this sense, interactive feedback between marketing tasks and R&D activities is essential as shown in figure 3.13 (p.113).

Moreover, the "*Network*" model of innovation is emerged subsequently to emphasize the knowledge accumulation and external linkages for firm's continuous innovation (Rothwell, 1992).

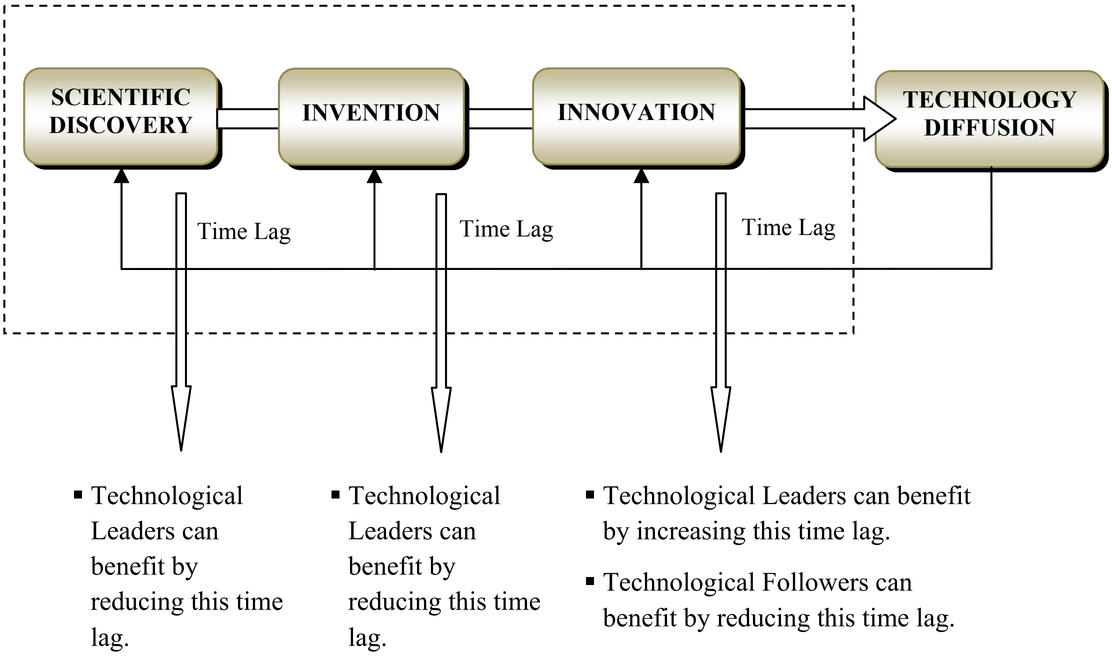


Source: Adapted from Rothwell (1992) and Tidd et al. (2005)

Figure (3.13): Integrative Innovation Model

3.4.4 Dynamics of Technology Diffusion

The success of innovation does not depend only on its technical achievement to solving problems but rather on its acceptance degree in the marketplace and its diffusion dynamics. Innovations as technical solutions are propagated to the marketplace over time through specific channels such as organizations, groups or individuals. There are often significant time lags between a scientific discovery, its use in an invention, and the time needed to apply the invention as an innovation. Similarly, there is generally a diffusion time delay to commercialize the innovation and its utilization by firms. The length of the time lags in the invention- innovation-diffusion chain can have a significant impact on the effectiveness of the technological strategy employed by firms as follows: 1) Technological leaders can increase the effectiveness of their strategy by reducing the time lag between scientific discovery and invention, and/or by lessening the time lag between invention and innovation. By reducing either one or both time lags, firms can effectively increase the rate at which they generate technological innovations. This in turn will effectively give the technological followers less time to adopt and exploit the new ideas. 2) Technological leaders can increase the effectiveness of their strategy if they are able to lengthen the diffusion time lag for competitors. If these firms can keep their original innovations from spreading quickly to other companies, they will be able to exploit the advantage and reap the benefits of the innovations for a longer period of time. Clearly, on the contrary, the technological followers could benefit by reducing the diffusion time lag to imitate the original innovations (Noori, 1990). This approach is clearly shown in figure 3.14.



Source: Adapted from Noori (1990)

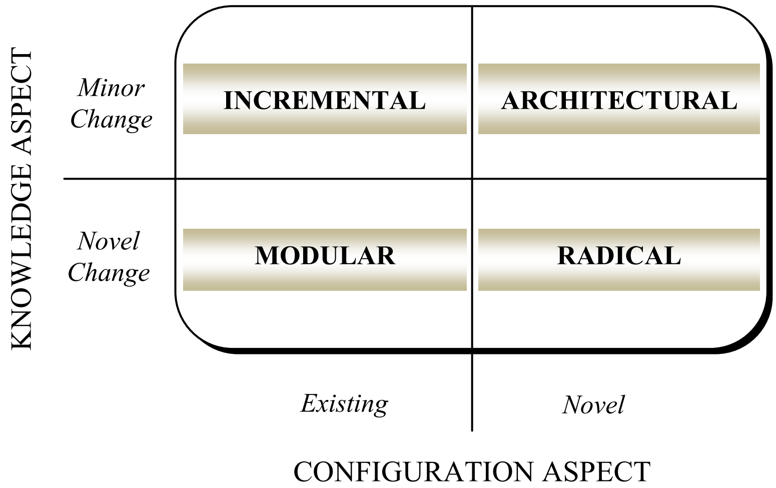
Figure (3.14): Invention-Innovation-Diffusion Chain

Many technologies, once diffused, would directly or indirectly result in the conception of the next generation of technology (e.g. dimensional seismic technology, mobile phone technology). This cycle then repeats itself after a given time lapse. Furthermore, depending on their focus and market strengths, firms might find it convenient to spend more time and effort commercializing an existing concept and tailoring it to create their own *"market niche"*. This approach provides a potential stepping stone to market supremacy. For instance, Japanese firms have clearly followed this approach. For many years, their strategy has been to take the ideas from other countries and use them to advantage to produce high quality products. The strategy the Japanese pursue on an international (i.e. macro-level) scale can be followed successfully by individual firms (i.e. micro-level) within an industry, especially if they share trade secrets (Noori, 1990).

3.5 INNOVATION OUTPUT DIMENSIONS

3.5.1 Innovation Technical Dimension

Innovation varies in its output technical dimension. Some innovations introduce relatively marginal technological changes to existing technologies, while others introduce drastic technological changes that open up new applications and markets. This classification, according to Narayanan (2001), leads to four major types of innovation: 1) *Incremental innovations*: This kind of innovations represents minor improvements or change to the elements of an existing technology configuration. The initiation and implementation of these innovations requires little new organizational knowledge, because they are aligned with existing organizational skills and capabilities. 2) *Modular innovations*: These innovations refer to significant changes in elements of knowledge (i.e., products, organizational practice, and technologies) without significant changes to the existing configuration of the elements. The initiation and implementation of these innovations would thus require an organizational understanding of the new components of the system. No significant new organizational knowledge concerning the configuration of these components would be required. 3) *Architectural innovations*: These innovations use existing knowledge (i.e. organizational practices and technologies) but reconfigure them in new or different ways. Thus their initiation or implementation requires an organizational knowledge of how existing components are to be configured into a new system. No significant new knowledge is required concerning the components themselves. 4) *Radical innovations*: These innovations represent revolutionary changes that require clear departure from existing organizational practices and technologies. They are typically not aligned with the organization's skills and capabilities and thus require significant new organizational knowledge concerning both the components of a system and the configuration of the system. Taxonomy of innovation technical dimensions is arrayed in figure 3.15 (p.116).



Source: Adapted from Narayanan (2001)

Figure (3.15): Taxonomy of Innovation Technical Output

3.5.2 Innovation Economic Dimension

The economic dimension of introducing new technological innovations to industry and society is becoming increasingly evident. For instance, the introduction of new technologies to oil industry will lead to: 1) Facilitating the technical operations being implemented under uncertainty and high risk. 2) Increasing the productivity and overall economic growth. 3) Lowering the product associated costs and increases production demand. 4) Resulting in a shift of the employment base towards more jobs, higher wages and new skills required which in turn will promote the output of the education and training systems. 5) Expansion of the market base through product better quality and variety. 6) Enabling the industry to compete globally. 7) Improving flexibility of response to the challenges made by changing competitiveness environment and geopolitical influences.

3.6 CONCLUDING REMARKS

In today global competitive environment, the technological innovation as a "*Black Box*" becomes the major hinge for creating the firm's sustainable competitive advantage. The success of technological innovation in any industrial arena is a complex and arduous task which can not be made over night or done in a clear-cut path. Rather, it is an integrative process which entails commitment and interactions of all key players and establishment of many appropriate institutional rules. In addition, innovations are largely dependent upon, or affected by, numerous internal and external elements. Amongst those elements emphasis has been laid on; the organization characteristics and structure, existence of entrepreneurial leadership within the organization, technological absorptive capacity of key personnel, institutional support, market demand, competitiveness impact, availability of venture capital, and formulation of technology strategy.

Chapter Four

THE LIBYAN PETROLEUM INDUSTRY IN PERSPECTIVE

4. THE LIBYAN PETROLEUM INDUSTRY IN PERSPECTIVE

4.1 INTRODUCTION

Libya is located in North Africa with an area ninety percent of which is desert. Libya is endowed with oil since early 1950s and its proven reserve of crude oil is the largest among the African countries. The less diversified economy of Libya is dominated by hydrocarbon earnings. In this sense, Libya needs to use strategically the oil windfalls to diversify its economic revenues and facilitate the transition to a competitive, knowledge-based economy.

This chapter is basically dedicated to overview the Libyan petroleum industry. In the subsequent section the impact of hydrocarbon on national economic performance are demonstrated, the oil and gas reserves and petrochemical exports of Libya will be illustrated, and an idea about petroleum licensing agreements will be given. The section three displays the structural aspects of Libyan oil sector such as the national oil corporation, the manpower structure and the fiscal turnovers. In section four the main characteristics of upstream industry in Libya will be articulated including national companies of producing oil & gas, and exploration & drilling operations. Characteristics of down stream industry such as national companies of oil & gas processing, refining infrastructure, pipeline network and natural gas processing will be all taken place in section five. Research and Development activities in Libyan petroleum institute are in essence demonstrated in section six. The final section is devoted to highlight the motives to petroleum technology development in Libya.

4.2 OIL DRIVEN ECONOMY

4.2.1 Role of Hydrocarbons in National Economic Growth

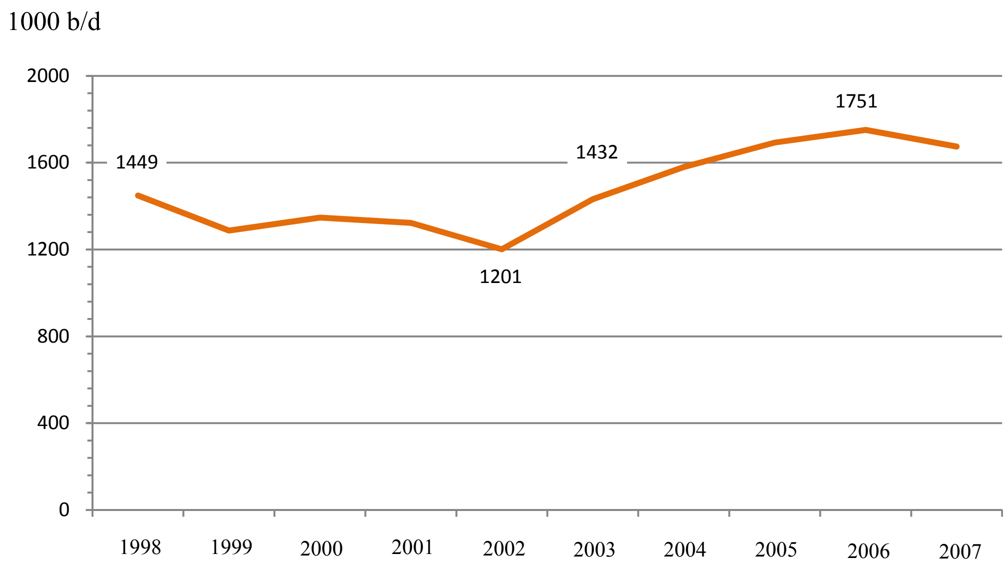
At the time of independence (195l), the Libyan economy was based mainly on agriculture, which employed more than 70 percent of the labour force, and contributed about 30 percent of the GDP, dependent on climatic conditions. Later in 1961 substantial quantities of oil had been discovered and greatly supported the country's socioeconomic development. Nowadays, Libya is a member of the Organization of Petroleum Exporting Countries (OPEC) and holds the largest proven oil reserve in Africa followed by Nigeria and Algeria (OPEC, 2007). The Libyan economy is dominated largely by hydrocarbon sector which representing about 72 percent of GDP in nominal terms, 93 percent of government revenues, and 95 percent of export earnings. Besides oil revenues constitute the principal foreign exchange source. As a result, Libya appears to be one of the less diversified oil-producing economies in the world. Despite efforts to diversify the economy and encourage private sector participation, extensive controls of prices, credit, trade, and foreign exchange constrain growth (World Bank, 2006).

Economic performance of Libya has been shaped by changes in oil revenues. At 2.6 percent per year on average, real GDP growth was modest and volatile during the 1990s, reflecting the inefficiencies of the state-driven economy, stagnant oil production and revenues, and the impact of economic sanctions. Since 2000, real GDP growth has been boosted by high oil revenues, reaching 4.6 percent in 2004 and an estimated 3.5 percent in 2005. Despite the country's relatively high per capita GDP, government mismanagement has led to high inflation and increased import prices, resulting in declining living standards. Reflecting the heritage of the command economy, three quarters of employment is in the public sector, and private investment remains small at around 2 percent of GDP (World Bank, 2006).

Libya has the potential to raise oil production and revenues significantly in coming years given its large reserve base. Cumulative oil production to date is equivalent to 60 percent of present estimates of recoverable reserves, but gas production is less advanced than oil, with cumulative production only 12 percent of reserves. Mean estimates of yet undiscovered, recoverable reserves are significant, about 20 percent of currently proven reserves. With current investment plans to raise capacity, Libya's production could increase substantially considering current OPEC quota shares. Over the long run, alternative scenarios project the net present value of the government's hydrocarbon revenues at between 7.3 to 19.8 times the levels of 2005 GDP. Oil wealth could generate a sizeable permanent income stream for Libya, ranging from 29 percent of 2004 GDP in a conservative reserve/price scenario, to above 50 percent of 2005 GDP in more favourable scenarios (World Bank, 2006).

4.2.2 Oil and Gas Production and Reserves

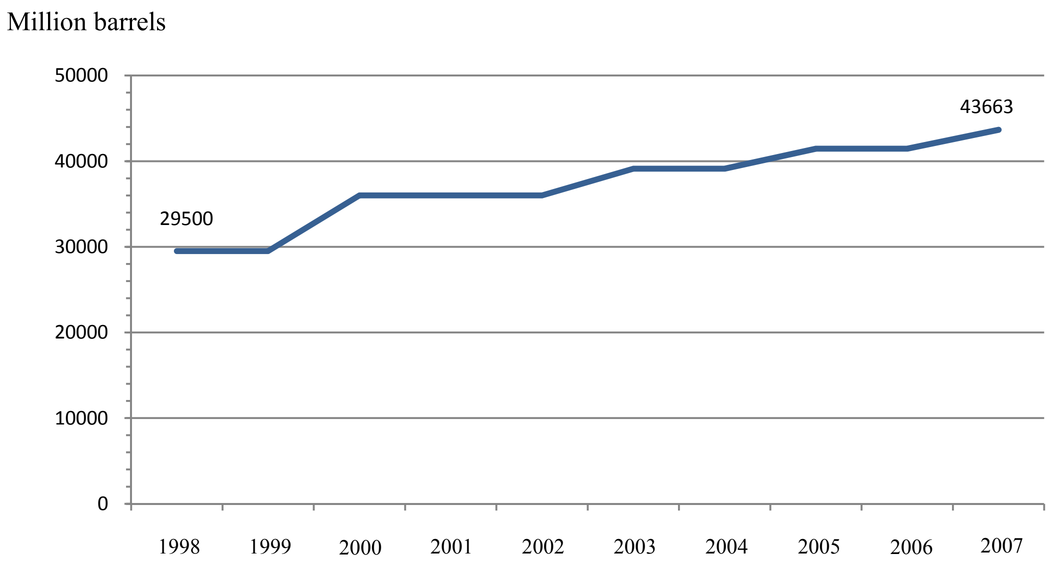
Over the period of 1998-2007, crude oil production in Libya has accelerated since 2003, which witnessed noteworthy increase to 1.43 million barrels per day from 1.2 Mb/d in 2002, or by 19.2 percent growth over 2002. Production growth has accelerated further in 2004, and although the year-on-year percentage growth was less in 2006, overall production kept increasing in order to meet world market demand. However, the oil production in Libya has grown sharply by 45.8 percent from 1.2 Mb/d in 2002 to 1.75 Mb/d in 2006 (OPEC, 2007). Figure 4.1 shows the year-on-year change in the average of crude oil production in Libya.



Source: OPEC (2007)

Figure (4.1): Crude Oil Production in Libya (1998-2007)

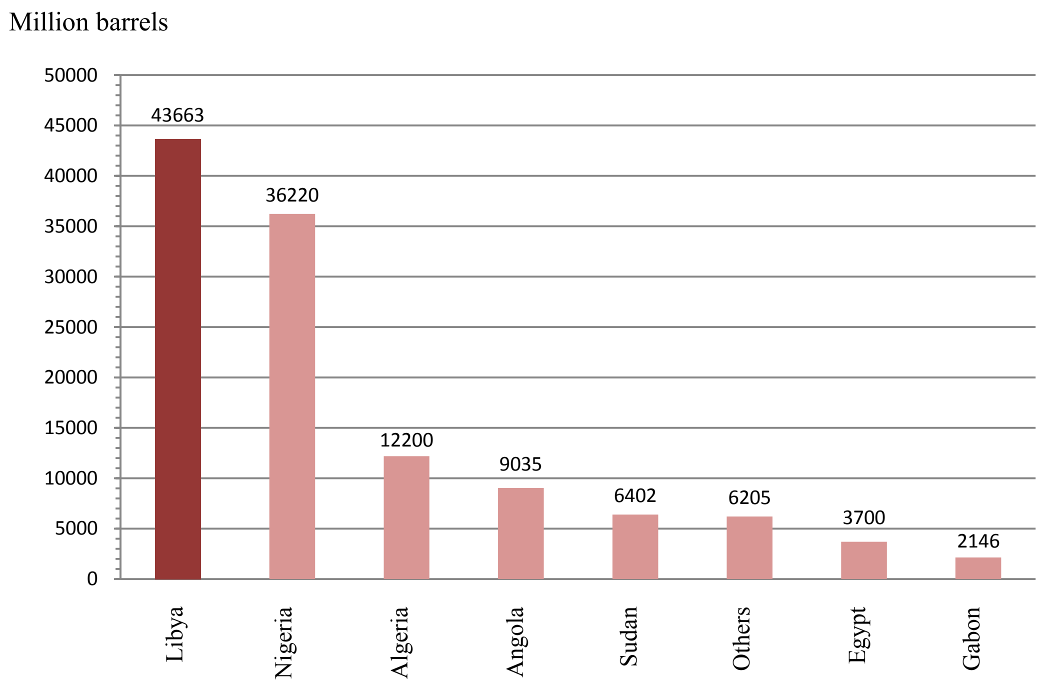
Libya continues keenly many onshore & offshore exploration operations along with many international partners to increase its proven crude oil reserve and substitute consequently the quantities produced to meet augmented energy demand. The proven crude reserve has grown remarkably by 48 percent during the 1998-2007 period from 29.5 billion barrels to 43.7 Bb (OPEC, 2007). Figure 4.2 (p.122) shows increment of proven crude oil reserve in Libya.



Source: OPEC (2007)

Figure (4.2): Proven Crude Oil Reserve in Libya (1998-2007)

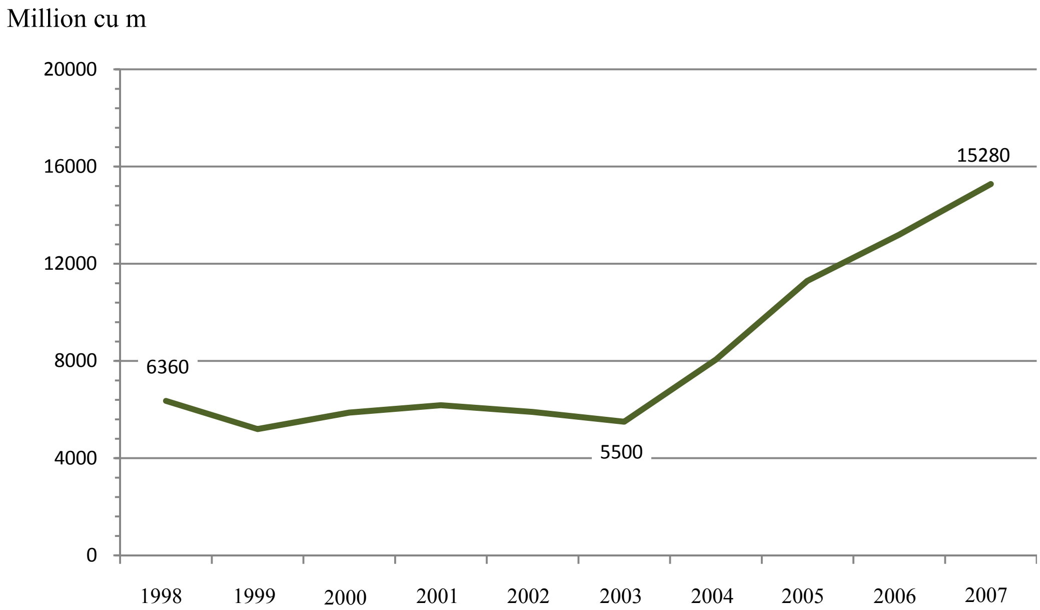
The proven crude oil reserve in Libya is considered the largest in Africa followed by Nigeria and Algeria (OPEC, 2007). Figure 4.3 illustrates Africa proven crude oil reserves in 2007.



Source: OPEC (2007)

Figure (4.3): Africa Proven Crude Oil Reserves in 2007

The National Oil Corporation of Libya (NOC) has paid considerable attention during the last years to develop the capabilities of natural gas production in Libya through realization of numerous gas investments such as Western Libya Gas Project (WLGP), which started production in the late of 2004 through the gas production facilities in Wafa onshore field and Bahr Essalam offshore field as well as the gas treatment facilities in Mellitah Complex. The natural gas production, therefore, has augmented sharply, by 177.8 percent growth, to 15.3 billion cubic meters during 2007 from 5.5 Bcm in 2003 (OPEC, 2007). Figure 4.4 demonstrates marketed production quantities of natural gas in Libya during 1998-2007.



Source: OPEC (2007)

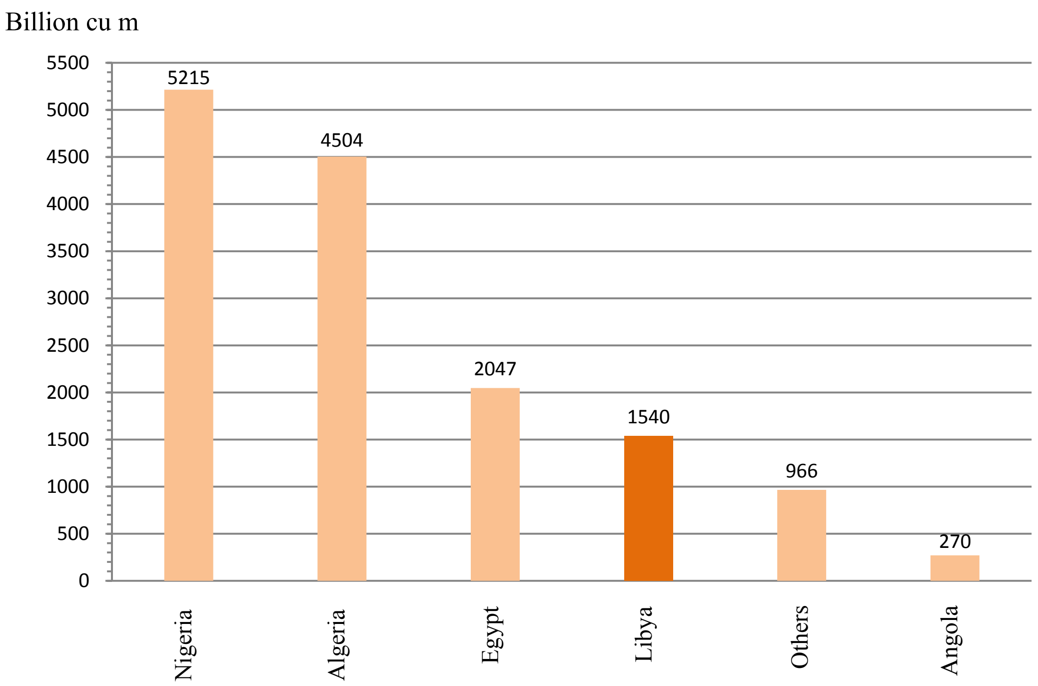
Figure (4.4): Marketed Production of Natural Gas in Libya (1998-2007)

Proven natural gas reserve in Libya has grown, by 14.4 percent, to 1.5 trillion cubic meters in 2002 from 1.31 Tcm in 2001. Throughout a period of six years from 2002 to 2007 proven natural gas reserve remained almost the same except a little reduction to 1.42 Tcm in 2006 (OPEC, 2007). The quantities fluctuation of proven natural gas in Libya during 1998- 2007 can be seen clearly in figure 4.5 (p.124).

Source: OPEC (2007)

Figure (4.5): Proven Natural Gas Reserves in Libya (1998-2007)

The proven natural gas reserve in Libya is ranked the fourth largest reserve in Africa after Nigeria, Algeria and Egypt in 2007 (OPEC, 2007). Figure 4.6 demonstrates proven natural gas reserves in Africa in 2007.



Source: OPEC (2007)

Figure (4.6): Proven Natural Gas Reserves in Africa in 2007

4.2.3 Petrochemical Exports

The Libyan petroleum sector produces and exports annually some considerable amounts of petrochemical products, as shown in table 4.1, which play fundamental role in sustaining the national economic growth.

Petrochemical Product	2001	2002	2003	2004	2005	2006
Methanol	591.6	715.3	659.0	600.0	594.5	640.6
Ammonia	131.6	151.6	196.3	137.6	128.8	135.0
Urea	740.4	717.5	775.0	758.0	701.8	777.6
Ethylene	146.0	91.4	140.0	91.0	140.4	150.0
Propylene	153.0	106.5	167.9	136.1	167.4	188.9
Mixed C_4	100.5	36.9	83.9	95.8	127.2	123.1
Polyethylene	75.4	37.9	99.3	74.4	69.3	115.3
Heat Gasoline	175.6	0	204.7	147.0	201.9	264.9
Total Exports (1000 M.T.)	**2114.1**	**1857.1**	**2326.1**	**2039.9**	**2131.3**	**2395.4**

Source: NOC (Survey Data)

Table (4.1): Libya Petrochemical Exports (2001-2006)

4.2.4 Petroleum Licensing Agreements

Petroleum licensing in Libya has followed three broad trends since its initial inception in 1955. The first was an initial period of concession agreements with various amendments including a sealed bidding round. This was followed by a second trend of joint venture agreement in the late 1960's and finally the establishment of a third phase of exploration and production sharing agreement (EPSA) which was first introduced in 1974 (NOC, 2007b).

Developments in the Algerian oil industry prompted Libya to issue a petroleum law in June 1955 which governed the granting of petroleum rights to foreign companies. In these early concession agreements, the country was divided into geographic zones and a system of rentals was applied with varying relinquishments according to the location of the concession. Expenditure obligations were limited and bonuses were not applied. A royalty of 12.5 percent of the value on the field was also applicable (NOC, 2007b).

By 1956 a total of fifty nine concessions had been awarded to foreign oil companies under these terms. However the petroleum developments occurring in Algeria led the Libyan government to revise the petroleum law after considerable consultation with the oil companies. The main changes involved increased rental charges, sealed bidding, percentage depletion provisions were abolished and pre-production expenses reduced from 20 percent to 5 percent in addition to the introduction of the "posted price principle" for calculating royalty payments. In 1965 a further set of amendments were made to the petroleum law. These included the use of discounts to be allowed in the posted price for tax purposes and the end of the use of royalties being treated as a tax credit. In addition the concession holder was allowed a US$ 0.5 allowance per barrel of oil produced as a marketing expense (NOC, 2007b).

By 1968 the second phase of license agreements was created. These joint venture agreements also involved establishment of the General Libyan Petroleum Corporation (GLPC) as a joint venture partner. The broad terms of these new agreements were generally favourable to oil companies, and set the scene for future licensing. Joint Venture Agreements however included the provision that rents and royalty payments and many other items of expenditure were no longer tax deductible and the foreign oil companies could not claim exploration expenses from their share of production. These joint venture agreements also included minimum financial commitments in the order of US$ 20-30 million over a ten year period. Companies entering into joint venture agreements included Aquitaine, Shell, AGIP and Ashland (NOC, 2007b).

In the early 1970's, considerable turmoil existed in the Libyan oil industry which mainly centred on the nationalisation or part nationalisation of the foreign oil companies interests. In addition, negotiations around the increase in the "posted price" caused considerable consternation amongst the oil companies. After nationalism and part nationalism (enforced state participation) the third set of licence agreements were drawn up. The EPSA-I agreements were simpler in outline than the former concession agreements. Broadly they offered the foreign oil company a percentage of the oil produced free of taxes and royalty payments. All exploration and foreign company costs were met by the foreign oil company. Exploration periods were generally set at five to six years with an exploitation period of thirty years. Onshore agreements were on an 81:19 production spilt in favour of NOC, and cost recovery was only allowable from the contractors' share of oil produced. In spite of these tough terms, Occidental, Elf, Esso, Braspetro, Mobil, and AGIP signed EPSA-I agreements. In the onshore Libyan area only Occidental co. made a profit under such an agreement in the NC74 areas, although oil indications were already present in wells drilled by previous operators in these blocks (NOC, 2007b).

These EPSA-I agreements were superseded by a fresh set of EPSA-II agreements in the 1980-81 period. The new versions were similar to EPSA-I contracts except the terms were harsher, the contractor oil percentage varied according to the location of the concession and the likelihood of finding hydrocarbons. These new agreements were also drawn up at a time of high oil prices and oil companies who wanted security of supply such as Deminex and Braspetro were obliged to explore for oil in addition to purchase it with numerous contracts that carrying heavy work programmes. Companies signing these new agreement included Deminex, AGIP, Shell, Rompetrol, BOCO, Coastal States, Elf, Occidental and Sun (NOC, 2007b).

In the mid 1980's with the background of oil price weakness, coupled with the withdrawal of American companies from Libya on the instruction of the US state department, a new set of petroleum contracts were drawn up known as EPSA-III agreements. The terms of the new contracts varied but were more favourable to the oil companies, many of which were new to Libyan exploration and these agreements also carried large work programmes. New companies included OMV and Fina, both of which had group commitments of over US$100 million on their licences. Other companies entering Libya under these agreements included Lasmo, INA and IPL (NOC, 2007b).

Substantial new acreage was offered under EPSA-III in 2000, as Libya pursued its strategic decision to open up more of its oil and gas sectors to international companies following the suspension of UN sanctions. The absence of truly global competition and full transparency in that bidding process resulted in some licenses being granted on what, in the light of most recent EPSA-IV round, now appear comparatively advantageous terms (NOC, 2007b).

Among areas seen as needing stronger provisions are the transfer of technology and the training of Libyan nationals and the incorporation of these requirements within the bidding process. Many of these issues were incorporated in the new EPSA-IV framework, under which a first exploration bid round was in September 2004. Rather than being a completely new departure, EPSA-IV builds upon previous frameworks, though with enhanced transparency and more open competition in the bidding process itself. It also features standardised terms for exploration and production contracts, provisions covering joint development and the marketing of associated natural gas discoveries, and non-recoverable bonuses. The international oil company (IOC) has to commit to bearing all costs over the first five years and publicly declare the amount to which it is committed, while management of the project is assigned to a committee comprising NOC representatives and the outside investor (NOC, 2007b).

The extremely competitive level of bidding under EPSA-IV, with foreign partners pledging a higher proportion of future production to NOC than has been seen for nearly two decades, reflects both today's higher energy price environment and, possibly, strategic decisions taken by some of the winning bidders to build their presence in Libya, with a view to expanding their role in developing its huge hydrocarbon potential in the future. According to most parties involved in the first bidding round, in which sixty three companies took part, two major issues made it an outright success: Firstly, the transparency of the process, which had widely been praised by oil and gas operators worldwide as setting new standards. Secondly, the opening of Libya to American oil companies, which have been barred for over eighteen years, thirteen out of fifteen exploration areas were on offer (NOC, 2007b).

From Libya's prospective, it has strengthened international confidence and yielded a larger share of future revenue streams, to be invested both in upgrading the nation's infrastructure and in broader social and economic development, than might have been anticipated. Moreover, NOC of Libya has lately signed some exploration and production sharing agreements with many American and non-American companies, such as; Chevron Texaco; Amerada Hess; Exxon Mobile; Occidental, Shell (Holland and UK); Petrobras (Brazil); Repsol YPF (Spain); Agip (Italy); Eni (Italy); Lasmo (UK); PetroCanada (Canada); Verenex (Canada); OMV (Austria); Wintershall (Germany); Total (France); Schlumberger (France); Woodside (Australia); Liwa (UAE); Sonatrach (Algeria); Norsk Hydro (Norway); Statoil (Norway); Tatneft (Russia); Turkish Petroleum Overseas; Several Japanese companies such as Nippon Oil, Mitsubishi, Japan Petroleum Exploration (Japex), Teikoku Oil and Impex Oil; CNPC (China); Pertamina (Indonesia); and three Indian companies, Oil India, Indian Oil Corp. and ONGC Videsh. The agreements have been for exploration periods of five years extendable to twenty five years under certain conditions (NOC, 2007b; EIA, 2006).

4.3 STRUCTURAL ASPECTS OF LIBYAN OIL SECTOR

4.3.1 National Oil Corporation of Libya (NOC)

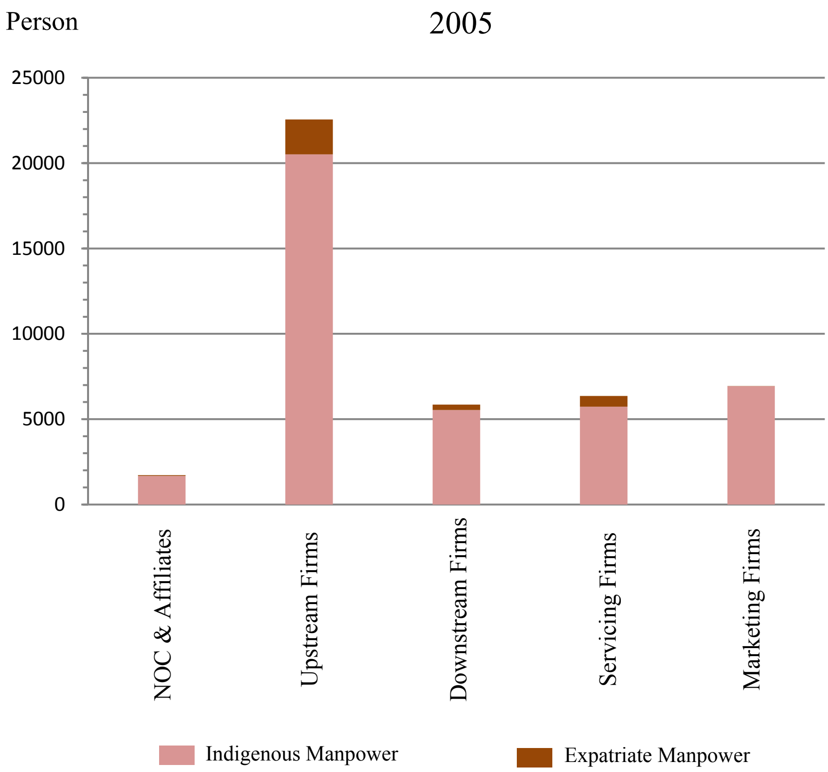
The state- owned National Oil Corporation (NOC) was established on 12 November 1970, under Law No.24 of 1970, replacing the General Libyan Petroleum Corporation which established under Law No.13 of 1968 to assume the responsibility of the oil sector operations. It was later reorganized under decision No.10 of 1979 by the General Secretariat of the General People's Congress, to undertake the realization of the objectives of the development plans in the area of petroleum industry, supporting the national economy through increasing, developing and exploiting the oil reserves, operating and investing in these reserves, and to achieve accordingly optimum returns.

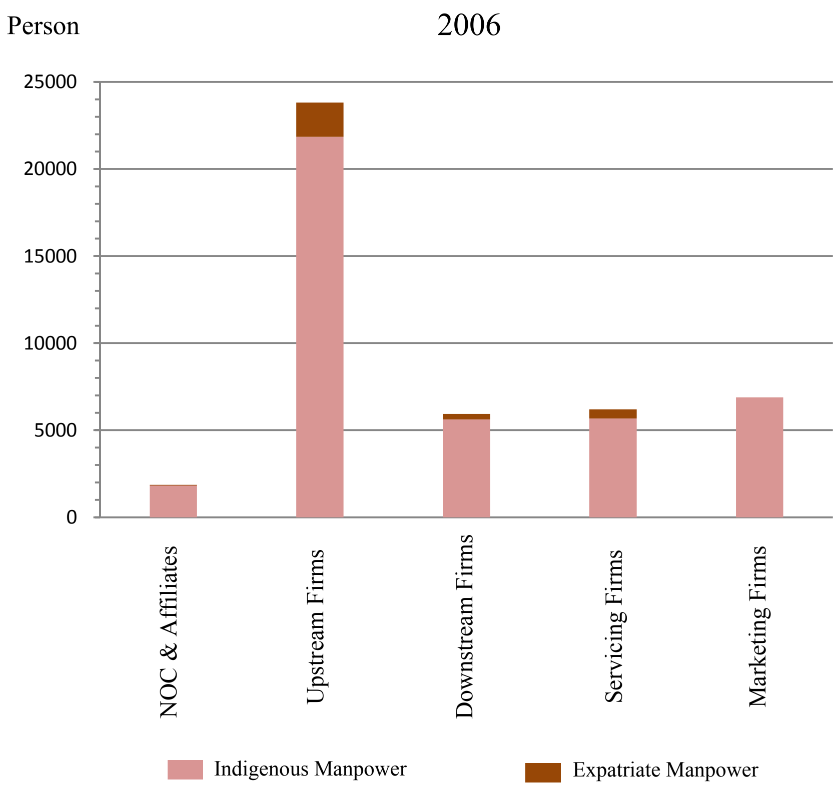
In this respect, NOC carries out exploration and production operations through its fully owned affiliated companies or in participation with other specialized international companies under various service agreements. These activities cover wide areas, both onshore and offshore, throughout the country’s territorial waters and continental shelf. In downstream industry, NOC owns numerous petroleum refiners and oil and gas processing plants scattered all round the geographical nationwide. To marketing its petroleum products inside the country and overseas NOC uses its network of specialized firms. Besides, among the affiliates of NOC is the Libyan Petroleum Institute (LPI) which carries out research and technical studies related to oil industry and conducts technical analysis and laboratory tests throughout various stages of exploration and production of oil & gas, as well as for several petroleum products (NOC, 2009a).

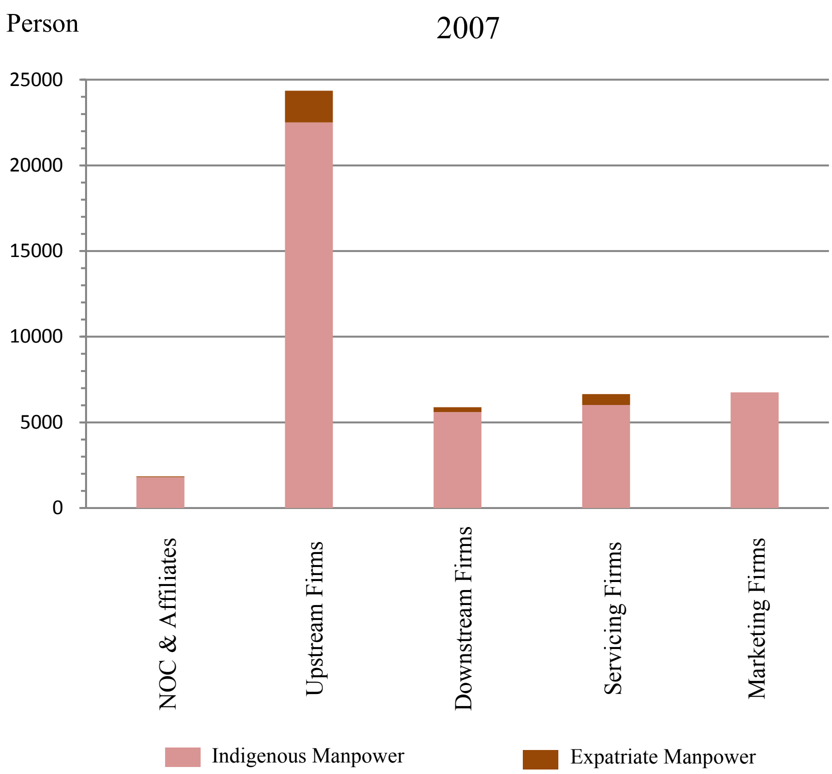
Moreover, NOC owns national service companies, some based locally and others abroad, which carry out oil well drilling and work over operations, provide all kind of drilling and production facilities, lay and maintain oil & gas pipelines, build and maintain oil & gas storage tanks, and carry out related technical and economic studies. Also, they provide the sector with other services, such as catering, procurement of materials and equipments, training & development, and recruitment of foreign personnel via international resources pool.

4.3.2 Structure of Manpower

The manpower in Libyan petroleum sector has witnessed 4.76 percent growth all over the period of 2005-2007. The large part of total manpower is allocated to up-stream industry, which in particular had 7.97 percent growth of manpower as from 22561 persons in 2005 up to 24361 persons in 2007. The expatriate manpower forms in average only 6.5% of total (NOC, 2005, 2006, 2007a). The structure of total manpower in Libyan petroleum sector is shown in figure 4.7 (pp.130-131).



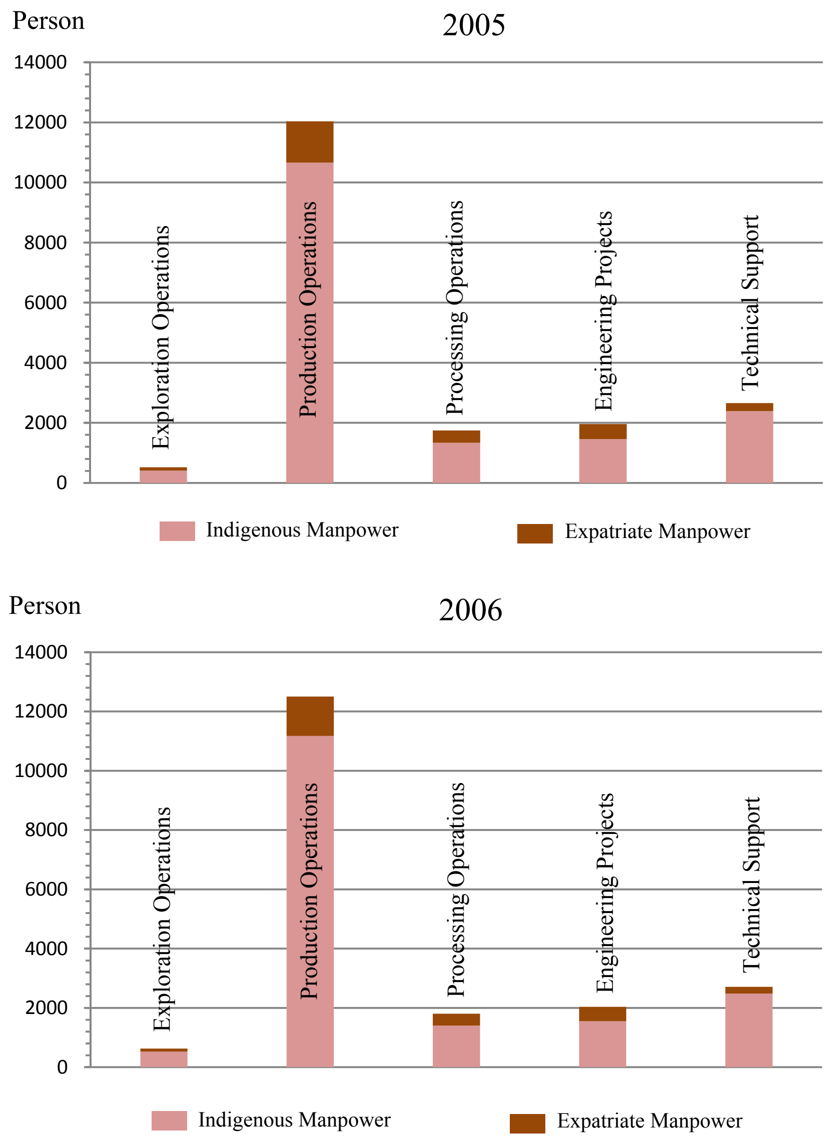




Source: NOC (2005, 2006, 2007a)

Figure (4.7): Total Manpower Structure of Libyan Petroleum Sector (2005-2007)

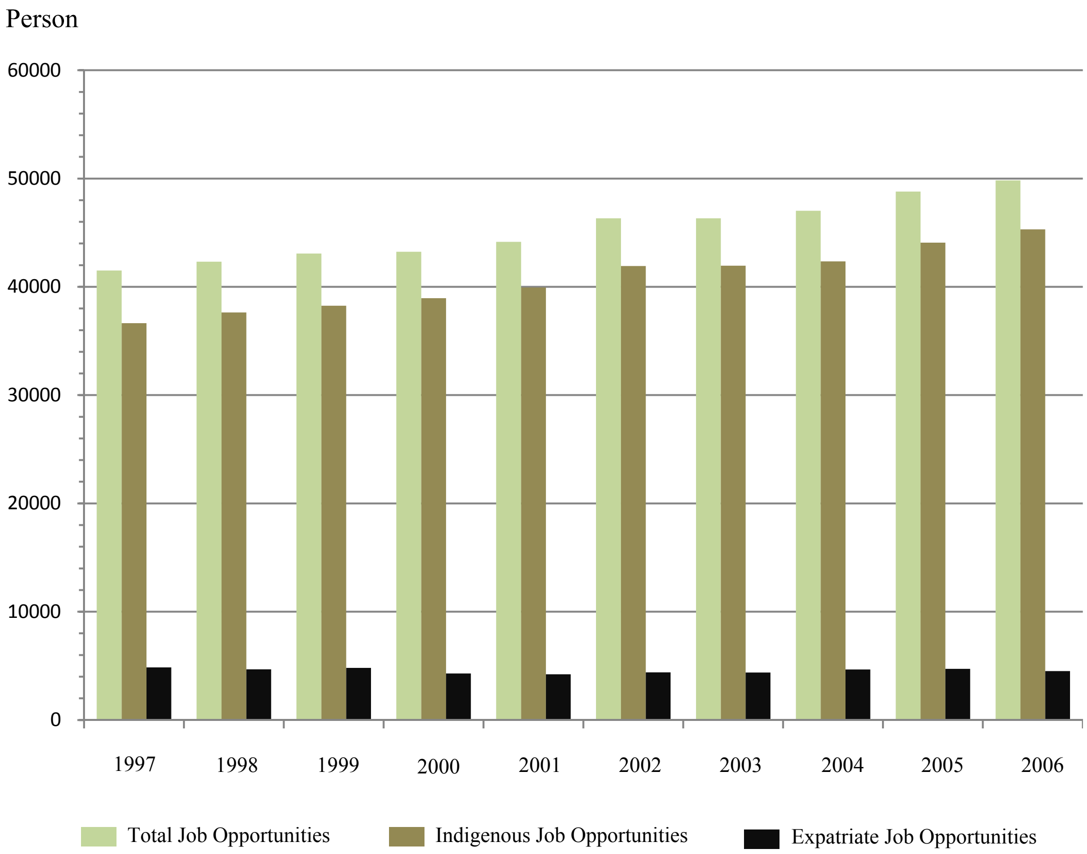
The technical manpower of Libyan petroleum sector which is allocated to exploration and production operations, processing activities, engineering projects and technical services has grown in total by 4.1 percent during 2005-2006. The production operations had in average about 63.5 percent of total technical manpower at that period of time. The manpower of production operations witnessed 3.9 percent growth in 2006. The expatriates formed in average 13.5 percent of total technical manpower during 2005-2006. The expatriate manpower reduced by 4.3 percent in 2006 (Survey data). Figure 4.8 demonstrates technical manpower structure of Libyan petroleum sector during 2005-2006.



Source: Survey Data

Figure (4.8): Technical Manpower Structure of Libyan Petroleum Sector (2005-2006)

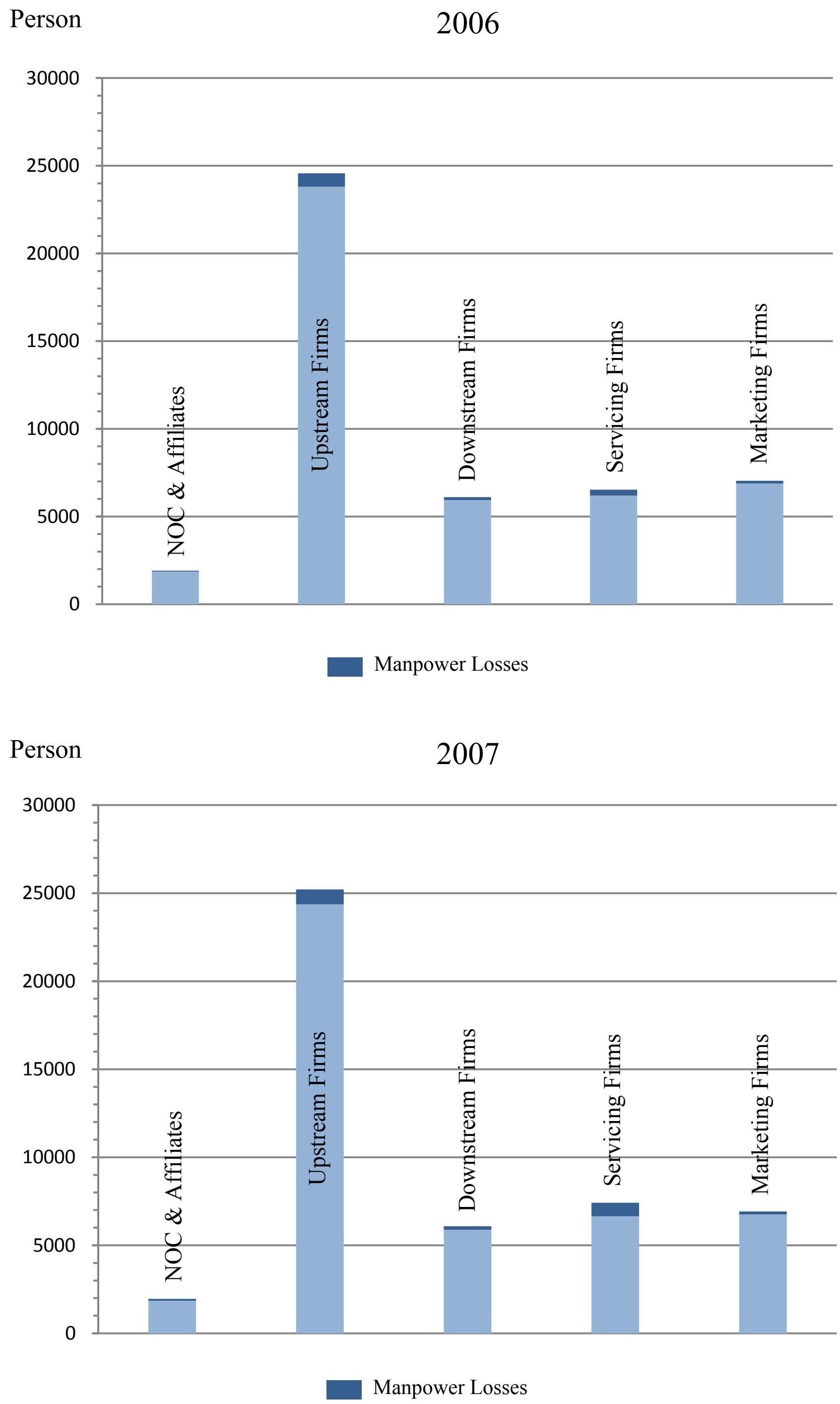
The Libyan petroleum sector is used to offer new job vacancies every year. The total job opportunities including assigned and vacancies have grown substantially by 20.1 percent in the last decade 1997-2006 (Survey data). The majority of job opportunities have been offered to nationals in order to subdue the raised unemployment in Libya, which is officially estimated at 17 percent of the total workforce, affecting mainly the younger and female population (UNDP, 2006b). The distribution of job opportunities in Libyan petroleum sector is shown in figure 4.9.



Source: Survey Data

Figure (4.9): Job Opportunities in Libyan Petroleum Sector (1997-2006)

The manpower losses in Libyan petroleum sector; either due to retirement, resignation, move, death or others; which form in average only 3.9 percent of total manpower have increased largely by 43.5 percent between 2006 and 2007. The up-stream industry had in average about 46 percent of total manpower losses at the same period (NOC, 2006, 2007a). Figure 4.10 (p.134) demonstrates structure of manpower losses in Libyan petroleum sector during 2006 and 2007.

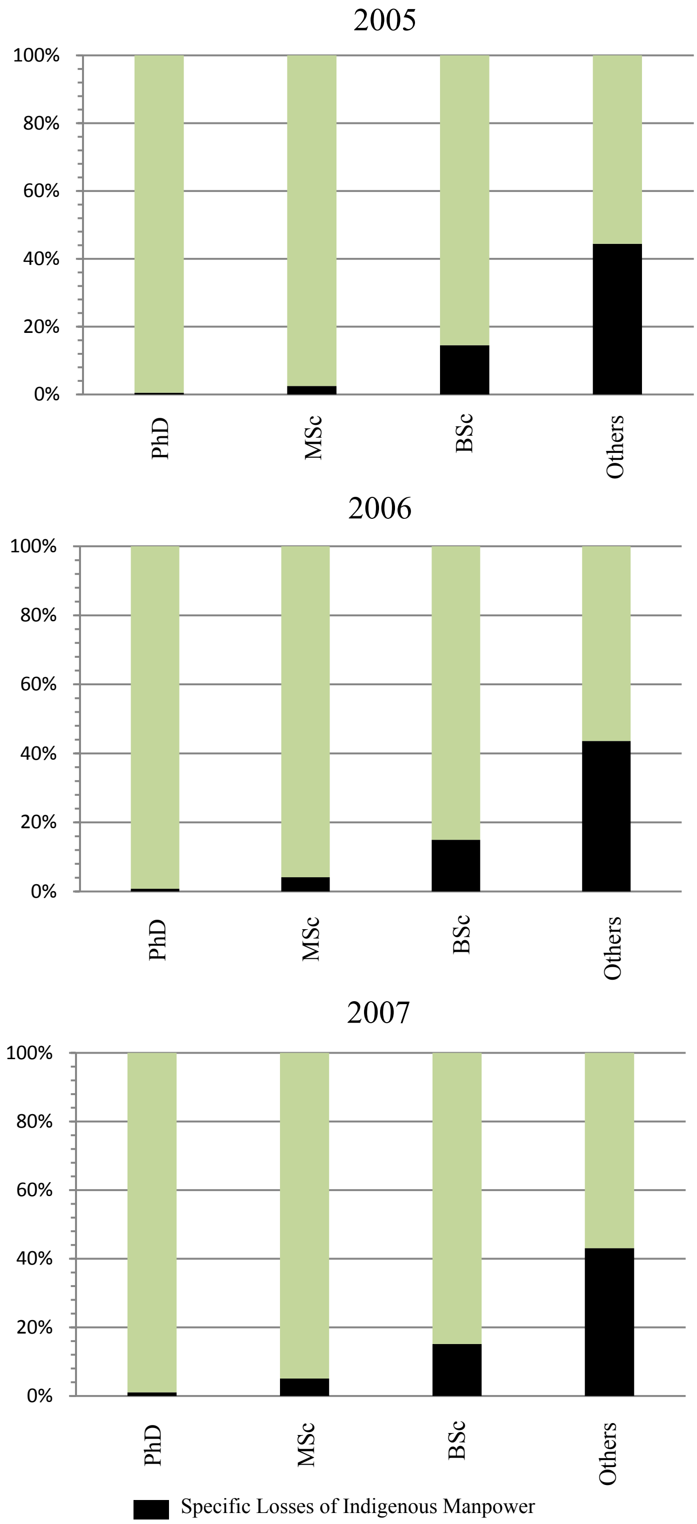


Source: NOC (2006, 2007a)

Figure (4.10): Manpower Losses in Libyan Petroleum Sector (2006-2007)

Furthermore, the scientific degree holders such as PhD, MSc, and BSc shaped in average 22.4 percent of indigenous manpower losses during 2005-2007, and some other professionals formed in average 77.6 percent of indigenous manpower losses in

Libyan petroleum sector in the same period of time (NOC, 2005, 2006, 2007a). Figure 4.11 shows structure of indigenous manpower losses in Libyan petroleum sector between 2005 and 2007.

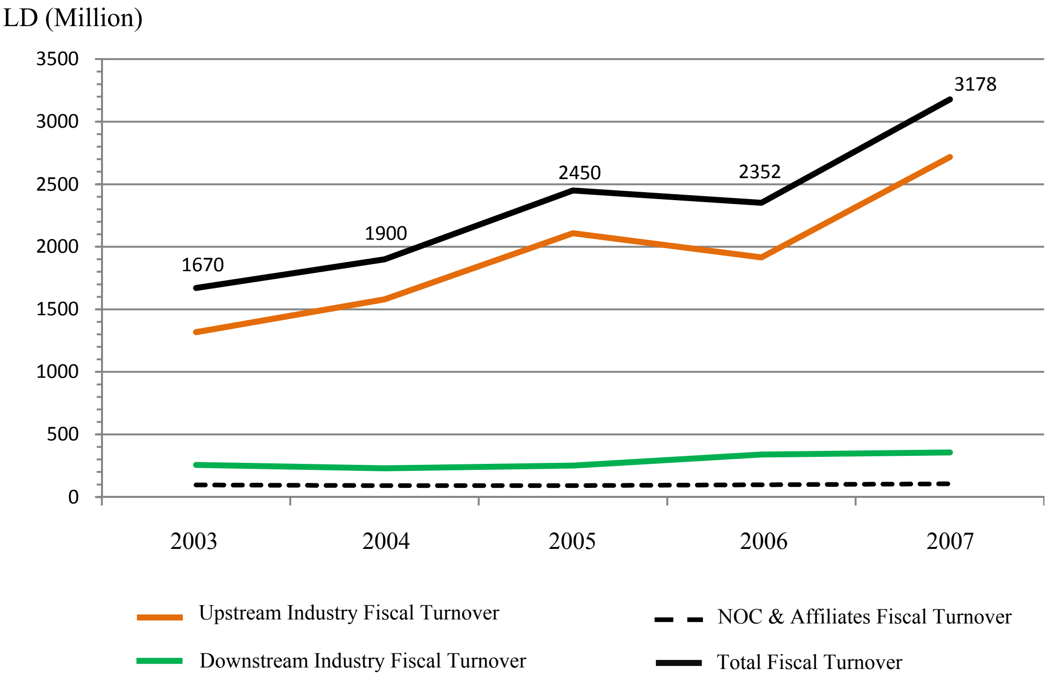


Source: NOC (2005, 2006, 2007a)

Figure (4.11): Structure of Indigenous Manpower Losses in Libyan Petroleum Sector (2005-2007)

4.3.3 Fiscal Turnovers and Sources of Fund

The Libyan petroleum sector is funded by the Libyan government jointly with other international oil partners under various funding agreements. The fiscal turnovers that funded in particular by the Libyan government have been increased tremendously by 90.3 percent during 2003-2007, as many huge petroleum investments have been achieved in upstream industry (Survey data). Figure 4.12 shows the escalation of fiscal turnovers of Libyan oil sector between 2003 and 2007.



Source: Survey Data

Figure (4.12): Fiscal Turnovers of National Oil Corporation and Subsidiaries (2003-2007)

4.4 CHARACTERISTICS OF UPSTREAM INDUSTRY

4.4.1 National Oil & Gas Producing Companies

The NOC's main subsidiaries of producing oil & gas are as follows:

– *Arabian Gulf Oil Company* (AGOCO): The wholly-owned NOC subsidiary, inaugurated on 7 December 1971 to carry out the oil operations started earlier by British Petroleum Company (BP), and to produce crude oil coming mainly from the Sarir, Nafoora/Augila and Messla fields. AGOCO is considered the largest oil producer in Libya, operates currently nine oil fields and its production was estimated by NOC in 2003 at around 430,000 b/d. In 1986, its Tobruk refinery started the processing operations with nameplate capacity of 20,000 b/d to produce LPG, light and heavy naphtha, kerosene, aviation kerosene, diesel, and heavy fuel oil. In addition, its Sarir refinery established in 1989 with total capacity of 10,000 b/d to meet the diesel demand of man-made river project, Sarir agriculture project as well as domestic use. AGOCO also manages Marsa El-Hariga oil & gas exporting terminal located on Mediterranean Sea (ACOCO, 2009).

– *Waha Oil Company* (WOC): The next largest oil producer in Libya established in 1986 to take over operations from Oasis Oil Company. The Waha Oil Company is working currently under joint venture shares of NOC (59.16%), Conoco (16.33%), Marathon (16.33%), and Amerada Hess (8.16%). WOC operates four oil fields and produced about 320,000 b/d as the average total production of crude oil per day for the period of 2001-2006.

Through use of seismic surveys along with geophysical and geological studies, Waha Oil Company evaluates its concessions and maps its geological formations and oil resources prior to drilling new oil and gas discoveries. The current concession and joint venture areas assigned to the company total 52,241 km² which is divided to 19 concessions and joint ventures. The company executed exploration operations, namely: 1) Seismic survey of 1,895 km using electrical methods. 2) Seismic survey of 6,185 km of seismic lines using refraction methods. 3) Gravity survey of approximately 29,563 km. 4) Magnetic survey of 7,477 km. 5) Survey of 167,124 km of 2D seismic lines. 6) Survey of 8,238 km of 3D seismic lines. 7) 202 exploration and delineation wells have been drilled (WOC, 2009a).

For production operations, total number of drilled oil and gas wells numbers 1,100 of which 800 are productive wells. The WOC implements annually programs for developmental, vertical, and horizontal drilling and evaluation of well performance, together with the execution of reservoir and mechanical maintenance to ensure productivity enhancement. Reservoir depths range from 3,000 to 7,500 feet for the developmental wells and 15,000 feet for exploration wells. The deepest well in Libya drilled by WOC was 19,210 feet in depth. The accompanying gas produced during crude oil operation is seen to be one of cleanest sources of energy, where it is used by the company for the operating of various production and services facilities (WOC, 2009b).

Furthermore, WOC has also established gas liquidation plants in a number of its oil fields. Part of the natural gas is shipped to local and foreign markets through pipelines connecting Waha 59 and Zelten oil fields to seaport of Sirte Oil Company. WOC's oil transmission lines extend from gathering, processing and pumping stations to Essider Terminal for global export. Companies such as Wintershall AG, AGOCO, Zueitina and Total use the WOC's oil and gas transmission facilities for the shipment of oil & gas which they produce (WOC, 2009c).

WOC has been among the companies most adversely affected by the US embargo during the last two decades. This is due to the fact that its oil fields are equipped mainly with US technology, for which WOC could not acquire needed spare parts. As a result, production at WOC's oil fields has fallen sharply, from about 1.0 million barrels per day at its peak in the late 1960s to around 350,000 b/d currently (EIA, 2006).

– *Zueitina Oil Company* : The Company established in 1986 based on the General People's Committee (Ministerial Cabinet) decision No. 351 of 1986 as a Libyan owned company with a mandate to carry out the whole range of oil E&P operations which was commenced by Occidental International back in 1966. After the termination of the frozen period and the return of partners, EPSA- IV Agreement was made between the National Oil Corporation, Occidental International, American, and OMV Libya Ltd. of Austria. This agreement signed on 23 June 2008, in which NOC holds 88 percent and partners 12 percent, and the capital budget divided equally (ZOC, 2009).

Zueitina Oil Company operates eleven joint venture oil fields and other four EPSA oil fields. The Company daily production average of crude oil is about 62,000 b/d for the period 2001-2006 according to NOC records. In addition, the average total production of gas per day is about 17.5 million cubic feet. In 1976, the well (D1) in field (103 D) registered one of the top production rates in the world which was 74,867 b/d. At the beginning of 2004, advanced drilling technologies (horizontally, curved, directional and multiple) were used and, consequently, wells production was multiplied into an average of three to four times. Such a rate would not have been possible, if these wells had been drilled vertically. The crude oil produced by Zueitina Oil Company is considered among the best Libyan crude oil and has been called 'Zueitina Blend' in the international market since the latest sixties (ZOC, 2009).

The company's crude oil exported via Zueitina Terminal. The company is handling up to 20% of the country's crude oil via Zueitina Terminal. This terminal is being shared by also other international companies such as ENI, Wintershall AG and OMV. Zueitina Oil Company supplies the local market with its needs of liquefied gas (cooking gas) through Brega Oil Company. Quantities of this gas are also exported outside the country (ZOC, 2009).

− *Harouge Oil Operations Company*: The origin of Harouge Oil Operations (formerly Veba Oil Operations) can be traced back to 1955, when Mobil Oil Company began its exploration in Libya. Due to the large investments involved in exploration and development, Mobil Oil Company signed a contract with the German Company Gelsenbrg AG which later was renamed to 'Veba Oil Libya' to share its exploration and production rights and obligations. In 1987, the joint operator, Veba Oil Operations, was established by the National Oil Corporation (51%) and Veba Oil Libya (49%), to explore, develop and exploit eight concessions, mainly located in central Libya’s Sirte basin. In 2002, Veba Oil Libya’s rights and obligations in these concessions were acquired by Petro-Canada. In 2004, Veba Oil Libya was renamed to 'Petro-Canada Oil Libya', and in 2008 Veba Oil Operations was renamed to 'Harouge Oil Operations'. In 2008, the National Oil Corporation and Petro-Canada signed six new exploration and production sharing agreements for the eight former concessions, and agreed that Harouge Oil Operations continues to develop and exploit the oil fields located in these concessions on behalf of the owners. The exploration activities within the new contract areas were assigned to be under Petro-Canada’s responsibility (Harouge, 2009).

In 2009, Harouge Oil Operations develops and produces petroleum from five of the contract areas with more than twenty fields. Current oil production potential from all fields is about 100,000 b/d. The crude oil is pumped from the various fields via export pipelines to Ras-Lanuf Terminal, where it is stored in 13 tanks and loaded on tankers for export. Harouge is also responsible for shipping of crude oil from fields operated by other operators, and therefore Ras-Lanuf Terminal handles about 450,000 b/d of oil and services an average of 15 crude oil carriers per month on behalf of the National Oil Corporation and of the international partners of NOC (Harouge, 2009).

– *Akakus Oil Operations Company*: The Company was established by virtue of an exploration and production sharing agreement between the National Oil Corporation (65%) and the European companies union (Repsol, OMV, Total) with a 35% stake. This consortium was approved by the General People's Committee (Ministerial Cabinet) resolution No. 802 issued on 06 December 1994. The Company activities are limited to exploration and production of oil for the benefit of share holders. The crude oil pipeline project from El-Shararah field to the storage tanks in Zawia on the coast was executed with a total length of 723 km and a diameter of 30 inches (Akakus, 2009).

– *Mellitah Oil & Gas Company:* The company is an upstream gas production & processing firm, established in late 2008 as a result of combination of two petroleum companies' work in Libya, ENI Gas and ENI Oil, and partnership of NOC. The company manages and operates the West Libyan Gas Project (WLGP) and carries out the operations of the gas production facilities in Wafa onshore field and Bahr Essalam offshore field as well as the gas treatment facilities in Mellitah complex. These facilities have a design capacity of 10.0 billion cubic meters per year of natural gas of which 8.0 billion cubic meters per year is exported to Italy and 2.0 Bcm per year is delivered to the local market. The facilities are also designed to produce 60,000 b/d of stabilized oil and 39,000 b/d of condensate, in addition to 15,000 b/d of liquid Propane and 13,000 b/d of liquid Butane and 530 metric tons per day of elemental Sulphur. The crude oil, condensate and LPG products are being exported from Mellitah harbour. Elemental sulphur also is being recovered and exported from Mellitah harbour utilizing the most advanced international technologies (Mellitah, 2009).

Mellitah complex is located about 22 km east of Zwara City, the complex covers an area about 355 hectares and consists of oil and gas treatment facilities, crude oil and products storage tanks, LPG and solid Sulphur loading facilities and all required utilities including gas and steam turbines for power generation. The complex consists mainly of two plants, one for treating the oil and condensate production from Wafa field whereas the other plant treats the gas and condensate coming from Sabratha offshore platform (Mellitah, 2009).

The Wafa coastal plant is designed to treat the oil and NGL coming from Wafa field with a total design capacity of 76,300 b/d. The Mellitah plant treats the gas and condensate production arriving from Sabratha offshore platform with total capacity of 695 million cubic feet per day of gas, 31,000 b/d of liquids and 450 metric tons of solid sulphur. It is worth mentioning that the handling and export of El-Feel crude production through the Mellitah harbour export facilities has commenced on 2 November 2005 after implementing the necessary modifications on the export facilities to enable them to handle tankers of 1.0 Mb capacity (Mellitah, 2009).

– *National Well Drilling Company* (NWD): Established in the late of 1987 as a fully-owned NOC subsidiary to carry out all kinds of well drilling services for both onshore and offshore petroleum operations, well work-over, well cementing, shale analysis surface, and water well drilling. NWD owns seventeen drilling rigs which can be used to drill oil wells up to depth of 20,000 ft in addition to performing about 45% of all petroleum drilling activities in Libya (NWD, 2009).

4.4.2 Exploration and Drilling Operations

Libya has been a global favourite for hydrocarbon exploration ever since 1956. This attraction was primarily a result of the phenomenal success rate of oil discovery in the Sirte Basin where 19 of the 21 giant fields, with recoverable reserves of 40 billion barrels of oil, are located. The ease of exploitation enhanced the drive for hydrocarbon exploration in neighbouring basins to the west (Ghadames) and southwest (Murzuq) where the search for hydrocarbons continues unabated. It is worth noting that exploration and drilling activities between 1957 and 2004 were carried out as follows: I) 1,200,000 km of 2D seismic survey executed. II) 30,500 km^2 of 3D seismic surveyed during the period 1993-2004. III) 2,286 exploratory wells drilled. IV) 770 oil and gas discoveries as a result of exploration activities with 33 per cent success ratio (NOC, 2009b).

More recently, all area awarded up to 2007 by NOC for onshore and offshore exploration totalled 764,338 km^2, in which 594,443 km^2 for onshore exploration that represents 33.7% of all Libyan geographical area. The exploration and drilling activities in that year were achieved as follows: I) 36,472 km of onshore 2D seismic and 18335 km for offshore. II) 12,949 km^2 of onshore 3D seismic and 5,095 km^2 for offshore. III) 190,872 km of magnetic and gravity surveyed. IV) 95 exploration wells and 36 delineation wells drilled. V) 139 wells developed. VI) 1433 tasks of well work over performed. VII) 13 new discoveries with 700.8 Mb of oil reserve, in which 195.6 Mb can be recovered. VIII) 621 Bcf of gas reserve, in which 398 Mb can be recovered. IX) 12.2 Mb of condensate, in which 7.0 Mb recoverable reserve (NOC, 2006).

4.5 CHARACTERISTICS OF DOWN-STREAM INDUSTRY

4.5.1 National Oil & Gas Processing Companies

The NOC's main subsidiaries of oil & gas processing are as follows:

– *Sirte Oil Company* (SOC): The Company was known in the past as ESSO Standard Libya Inc., the first company to discover oil in commercial quantities in Zelten field in 1959. Sirte Oil Company originally established in 1981 to take over the holdings of Exxon (the parent company of ESSO Standard) in Libya. In 1986, the SOC took over the assets of Grace Petroleum, one of the five US companies forced by the US government to leave Libya in that year. The SOC is considered one of the largest fully-owned operating companies of NOC. Its diverse operations include the exploration, production and manufacturing of oil and gas. The SOC operates the Raguba field in the central part of the Sirte basin. The field is connected by pipeline to the main line between the Nasser field, one of the largest in Libya, and Marsa El-Brega Terminal. Beside Nasser, the SOC is in charge of two other gas fields (Attahadi and Assumud). The average crude oil production of SOC per day is about107, 000 b/d for the period 2001-2006 (SOC, 2009).

The SOC's manufacturing activities are being done in its complex at Brega industrial region, and include the following: 1) Refining of crude oil with a capacity for processing 10,000 b/d to produce regular Gasoline, Kerosene jet fuel, Diesel oil, Naphtha, and heavy fuel oil. 2) Liquefaction of natural gas at Marsa El-Brega liquefied natural gas (LNG) plant with operational capacity of 120,000 b/d. 3) Manufacturing of petrochemicals which comprises; two Methanol plants each having a production capacity of 1,000 metric tons per day, both established in 1978 and 1985; two Ammonia plants, one having a production capacity of 1,000 Mt/d and one having a production capacity of 1,200 Mt/d, both established in 1978 and 1983; and two Urea plants, one having a production capacity of 1,000 Mt/d and one having a production capacity of 1,750 Mt/d, both established in 1981 and 1984. The combined total production capacity for the three products reaches 6,950 Mt/d. All products are marketed by the Brega Marketing Company (BMC), the sales arm of NOC (SOC, 2009).

– *Ras-Lanuf Oil and Gas Processing Company* (RASCO): The firm is a fully owned subsidiary of NOC, established in 1982 to manage and carry out petroleum refining operations and produce various petrochemical products. Its petrochemical complex is considered the largest major project that created for petrochemical production ever since discover of oil in Libya. The complex encompasses the following facilities:1) A refinery plant with a capacity of 220,000 b/d. 2) Ethylene plant utilizing naphtha as a feed stock to produce 1000 metric tons per day of Ethylene having purity of 99.9 mol%. The plant is designed to produce Ethylene (904 Mt/d), Propylene (470 Mt/d), Mixed C4 (357 Mt/d), Pyrolysis gasoline (885 Mt/d), and process fuel oil (120 Mt/d).3) Polyethylene plant produces 160,000 metric tons per year of HDPE and LLDPE using UCC gas phase technology. Most of production exports to the international market after meeting local needs. 4) Associated utilities facilities including Ras-Lanuf Harbour, which is located inside the complex to export products, and RASCO Harbour Liquid Loading System (RASCO, 2009).

– Azzawia *Oil Refining Company* (ARC): The Company is a wholly owned subsidiary of NOC. It operates the first NOC's refinery which was built by Snamprogetti Co., Italy and inaugurated on 1 September 1974 to produce Naphtha, Kerosene, light and heavy gas oil and heavy fuel oil with total capacity of 60,000 b/d. In 1977 production capacity was doubled to 120,000 b/d. The refinery was designed to produce products to meet latest specifications of international standards. It is also equipped with environment preservation instruments to maintain strict air and water quality standards. Furthermore, this refinery is supplied with all associated units for utility needs like generation of power, steam production via boilers, desalination units, air compressors and vast tank farm for storing crude oil, intermediate and finished products. In 1980, the company established a plant for asphalt production in order to meet the needs of local market with total capacity of 100,000 metric tons per year. In addition, another plant has been added to the company as well in 1983 to produce metallic oil for lubrication use with total capacity of 60,000 Mt/y. The ARC also manages its oil exporting terminal that located within its complex area on the Libyan coast (ARC, 2009).

– *Jowfe Oil Technology Company* (JOWFE): Established in 1983 to specialize in production and marketing of oil field chemicals, provide equipment for oil and gas well drilling operations, and offers technical services in offshore and onshore oil and gas exploration and production. The Company produces chemicals, which are used in drilling and exploration such as grinded Barite, Bentonite Calcium Carbonate and for backfill material for cathode protection. It also produces lost circulation material such as mica, wood, fibre, crushed nut shells with different sizes. In addition, the company produces special chemicals, which are used in oil well drilling operation, crude oil production and treatment processes, plants, refineries and for many other industries. These products include demulsifies, corrosion inhibitors, scale inhibitors, biocides, oxygen scavengers and chemicals for treatment of cooling water system. Moreover, Jowfe Company provides technical and engineering services for drilling fluids, wire line and production test for exploration and production wells. It also provides equipment services such as mud cleaning equipment, de-sander, centrifuge, shale shaker, fitting for casing & tubing and their spare parts (JOWFE, 2009).

4.5.2 Refining Infrastructure

Libya has five domestic refineries, with a combined nameplate capacity of approximately 380,000 barrels per day, significantly higher than the volume of domestic oil consumption (258,000 b/d in 2005). These refineries are all simple hydro skimming type refineries, but their products still meet market specifications due to the high quality of crude being processed. However, a plan for development of the refining industry has been approved by NOC to enable those refineries to become more economical and to meet newly implemented specification. Libya's refineries include; 1) *Ras Lanuf Export Refinery*, completed in 1984 and located on the Gulf of Sirte, with a crude oil refining capacity of 220,000 b/d; 2) *Azzawia Refinery*, completed in 1974 and located in north western Libya, with crude processing capacity of 120,000 b/d; 3) *Tobruk Refinery*, established in 1986 with crude capacity of 20,000 b/d; 4) *Brega Refinery*, the oldest refinery in Libya, located far eastern Libya with crude processing capacity of 10,000 b/d; and 5) *Sarir Refinery*, a topping facility started the operations in 1989 with 10,000 b/d of capacity.

Libya's refining sector reportedly was hard hit by UN sanctions, specifically UN Resolution No.883 of November 11, 1993, which banned Libya from importing refinery equipment. Fortunately, that sanction has been lately left, and consequently Libya is seeking a comprehensive upgrade to its entire refining system, with a particular aim of increasing output of Gasoline and other light products (i.e., jet fuel). Possible projects include; new hydro skimming refinery (20,000 b/d) in Sebha southern Libya, which would process crude from the nearby Murzuq field and meet local demand in remote south western Libya; and new export refinery (200,000 b/d) in Misurata, 200 km east of Tripoli.

In May 2002, NOC of Libya signed a $280 millions contract with South Korea's LG Petrochemicals Co. to upgrade Azzawia refinery. In addition, Ras-Lanuf also is slated for upgrading, although that project appears to have been delayed.

In addition to its domestic refineries, Libya represented in NOC also has operations in Europe through its overseas oil retail company, Tamoil. Through Tamoil, Libya is a direct producer and distributor of refined products in Italy, Germany, Switzerland, and (since early 1998) Egypt. Tamoil Italia, based in Milan, controls about 7.5 percent of Italy's retail market for oil products and lubricants, which are distributed through around over 2,000 Tamoil service stations. Libya's ability to increase the supply of oil products to European markets has been somewhat constrained by the fact that Libya's refineries extremely need upgrading, specifically in order to meet stricter EU environmental standards in place since 1996 (EIA, 2006).

4.5.3 Pipeline Network

Libya has a network of onshore & offshore oil, gas and product pipelines, exceeding three thousand kilometres in length, as well as completely equipped crude oil export terminals. Libya's oil fields are connected to Mediterranean terminals by an extensive network of pipelines all owned by NOC. Libya's main crude oil pipelines are as follows; Sarir to Marsa El-Hariga Terminal, Messla to Ras Lanuf Terminal, Waha to Essidera Terminal, Hammada El-Hamra to Azzawia Terminal, Amal to Ras-Lanuf Terminal, Intisar to Zueitina Terminal, and Nasser (Zelten) to Marsa El-Brega Terminal. In addition, Libya connecting to the European market by under water gas pipeline through ltaly (EIA, 2006).

4.5.4 Natural Gas Processing

Continued expansion of natural gas production remains a high priority for Libya for two main reasons. First, Libya has aimed success to use natural gas instead of oil domestically (i.e., for power generation) in order to freeing up more oil for export. Second, Libya has vast natural gas reserves and is looking to increase its gas exports, particularly to Europe. To expand its gas production, marketing, and distribution, Libya is looking to foreign participation and investment. In recent years large new discoveries have been made in the Ghadames and El-Bouri fields, as well as in the Sirte basin. Major producing fields of include Attahadi, Defa-Waha, Hatiba, Zelten, Sahl, and Assumud.

Libyan gas exports to Europe are increasing rapidly, with the Western Libyan Gas Project (WLGP) and $6.6 billion, 32-inch; 370-mile "Green stream" underwater gas pipeline came online in October 2004. Previously, the only customer for Libyan gas was Spain's Enagas. However, the WLGP (a joint venture between Eni and NOC) has now expanded these exports to Italy and beyond. Currently, about 8 billion cubic meters (280 billion cubic feet) per year of natural gas are being exported from a processing facility at Melitah, on the Libyan coast, via Green stream to south eastern Sicily. After that, the gas flows to the Italian mainland, and then onwards to the rest of Europe. Green stream with first flows coming from the Wafa onshore field near the Algerian border and the Bahr Essalam offshore field near Tripoli. Combined, the fields should be able to feed 280 billion cubic feet per year of natural gas into Green stream. Throughput on the Green stream line reportedly can be boosted to 385 Bcf per year if desired.

In 1971, Libya became the second country in the world (after Algeria in 1964) to export liquefied natural gas (LNG). Since then, Libya's LNG exports have generally languished, largely due to technical limitations which do not allow Libya to extract liquefied petroleum gas (LPG) from the natural gas. Libya's LNG plant, at Marsa El Brega, was built in the late 1960s by Esso and has a nominal capacity of about 125 Bcf per year. However, US sanctions prevented Libya from obtaining needed equipment to separate out LPG from the natural gas, thereby limiting the plant's output to about 15 percent of nameplate capacity, all of which is exported to Spain.

Now that sanctions have been lifted, however, companies are looking to Libya's LNG potential. In May 2005, Shell agreed to a final deal with NOC to develop Libyan oil and gas resources, including LNG export facilities. The deal came after lengthy negotiations on the terms of a March 2004 framework agreement. Reportedly, Shell is aiming to upgrade and expand Marsa El-Brega and possibly build a new LNG export facility as well at a cost of \$105 - \$450 millions. Shell also purchased exploration rights for five blocks in the Sirte basin (the company began seismic work in November 2005). In addition to Shell, other companies like Repsol are also interested in developing Libya's LNG export potential (EIA, 2006).

4.6 RESEARCH AND DEVELOPMENT ACTIVITIES

4.6.1 Libyan Petroleum Institute (LPI)

The Libyan Petroleum Institute (LPI) – previously known as Petroleum Research Centre of Libya (PRC) – was founded in 2005 by the General People’s Committee (Ministerial Cabinet) based on resolution No. 130. The PRC was founded by NOC in 1977 to provide national oil industry with technical and R&D support in both upstream and downstream sectors (i.e., exploration, production, and processing activities). LPI is one of the NOC wholly-owned subsidiaries, where NOC is the main custodian of LPI and the only financial sponsor, and the NOC chairman is the head of LPI board of directors.

The LPI undertakes research studies and scientific and economic consultations, provides technical and laboratory services for petroleum and industrial operations as well as promoting technology transfer in the oil and gas industry. The institute works to achieve the following tasks: 1) Setting up plans to perform research studies that focus on exploration, production, reservoir management, oil & gas processing and distribution, petroleum economics, and environment concerns. 2) Implementing fundamental and applied researches that lead to developing technology, processes, industrial and scientific plans which improve performance of oil industry technically, economically and environmentally. 3) Offering technical and laboratory services to exploration and production activities, reservoir engineering, oil refineries, gas processing, petrochemical manufacturing, petroleum transportation and distribution, and environment preservation whether to oil sector or other sectors. 4) Carrying out analysis and conformity tests of various petroleum & petrochemical products, substances, and equipment which are involved in oil industry. 5) Gathering and classifying research studies and all technical information related to national oil industry including samples of well cores, and information of exploration surveys and drilling operations. 6) Investigating problems of national oil industry and find out accordingly scientific and technical solutions through studies and consultations. 7) In association with other specialized organizations, drawing up standards and specifications for crude oil, gas, oil products, and material & equipment of oil processing. 8) Drafting regulations and technical directives which subject to application approval of national oil industry in all fields of exploration, production, oil refining, gas processing, petrochemicals, environment protection, and safety & occupational health. 9) Assessing inventions, prototypes, models and industrial designs related to all technical operations of national oil sector. 10) Organizing conferences, scientific symposiums, seminars, workshops and exhibitions inside and outside of Libya which lead to enhance performance and productivity of national oil industry. 11) Conducting different kinds of training programmes to gain vocational and scientific development of engineers, technicians, finance personnel, and technical management staff in oil industry (GPC, 2005).

The LPI basically represents the research community of national oil industry since a large part of its employees are devoted to research and development endeavours (i.e., senior management, technical consultants, research groups, and laboratory specialists & technicians), while the rest as supportive personnel (i.e., IT technical support, instrument maintenance services, procurement, logistical services, administrative & finance affairs, etc).

Qualifications of scientific and technical teams in LPI apparently diverse, as about 13.1% holders of intermediate diploma, 3.8% high diploma holders, 38.2% bachelors which is the largest group, 15.4% master degree holders, 6.1% doctorate holders, and 23.4% other professional qualifications (Survey data).

A variety of scientific and technical activities are being implemented on regular basis by LPI such as technical consultations (i.e., studies, surveys, reports, etc.), research papers, laboratory services (i.e. tests within/without studies), scientific events (i.e., conference, seminars, workshops, professional development programs, etc.), and issuing of LPI scientific journal. For instance, the scientific and technical activities for 2005 were as follows: I) 48 petroleum studies completed. II) 27 research papers & scientific articles were published. III) 21228 different samples were received for laboratory testing. IV) About 1180 km of 2D seismic processing achieved. V) 37 scientific events were held. VI) One issue of LPI Journal contains 16 research papers was published (LPI, 2005).

Furthermore, according to the survey data, LPI has many attempts towards technology development such as Flexible Integrated Well Log Analysis software package (FlexInLOG) which uses both deterministic and probabilistic methodologies that offer basic and advanced analysis of the mineralogical rock composition to determine some petroleum engineering parameters like porosity, permeability, and water saturation. FlexInLOG funded by LPI along with many other national oil companies and was marketed in 2003 to meet the following aims: 1) Providing detailed litho logical/mineralogical composition of heterogeneous rocks. 2) Determining hydraulic properties of fractured or non-fractured reservoirs (fracture density & width and matrix permeability). 3) Applying multi porosity rock models (3-5 porosity components). 4) Simulating more efficient fluid saturation models which distinguish between saturations of the different porosity components. 5) Incorporating the interpretation of the conventional well logs which are regularly used in Libya. In the second phase of software development new petro-physical tools were added such as; 1) Electromagnetic propagation tool (EPT). 2) Sonic array tool (SAT) with full acoustic wave. 3) Nuclear magnetic resonance (NMR). 4) Thermal decay time (TDT). 5) Geochemical logging (GL) with energy-selective neutron measurements. 6) Image logs (FMS, FMI, core, etc). 7) Production logs (PLT, spinner, etc).

Furthermore, jointly with NOC, Geological Hungarian Institute, and some operating oil companies LPI recently develops two software packages which called 'MESBAR' and 'SUPRA'.

The MESBAR (compartmental reservoir simulation) Software is a revolutionary new concept in reservoir simulation technique. This simplified and extremely fast mathematical simulation method of the actual in-field conditions enable the user to assess a quick and reliable estimation of the changes imposed due to abrupt market-oriented technical modifications. This basic concept of the simulator software is to provide a low cost, yet reliable tool to everyday operators of a reservoir, enabling the user to initiate multiple runs within short periods with different parameters. This Project has been divided into three phases; Phase 1: Development of scientific version, which includes building the mathematical model, checking the scientific equations, and testing the program system. Phase 2: Development of Beta version, where the software should be extensively tested by third party users to eliminate possible bugs, and give the final format of the software. Phase3: Preparation for commercial release of the software, where all the bugs detected during the Beta test should be corrected.

SUPRA, on the other hand, is a new and extremely mathematical solution to reservoir simulation that provide a completely new way of calculation, which reduces time and computer requirements significantly, yet providing high reservoir resolution, and application flexibility. Reservoir engineers have always felt the need for a fundamentally new mathematical solution for a complex numerical simulator to overcome shortages and difficulties of existing numerical models. The resulting software will serve to fill this demand with proper marketing, and should fulfil the requirements of different international petroleum companies and institutes.

4.7 MOTIVES TO DEVELOPING PETROLEUM TECHNOLOGY

Knowledge and skilled people are the key factors of development, main drivers of growth, and major determinants of competitiveness in the global economy. A nation could no longer rely on abundant natural resources and cheap labour, and that comparative advantage would increasingly be based on combinations of technical innovations and creative use of knowledge (Porter, 1990). In today's knowledge economy, knowledge produced by R&D, and inventions made in industrial laboratories are creating the so-called knowledge-industries. It is also getting increasingly difficult to separate the industrial, service, and agricultural sectors of the economy. This is because high-and medium-technologies are diffusing to all strata of all sectors of the economy, and to every aspect of our daily lives. These complex interactions are now driving the science and technology- based global economy, where R&D and production are horizontally integrated in the form of networks covering production sites and laboratories in a number of countries, making it possible to outsource knowledge, labour and other factors of production globally. More specifically, the motives behind petroleum technology development in Libya may be restricted to many factors, some of which are demonstrated in the following sections.

4.7.1 Petroleum Infrastructure and Prospective Aims

The evolution era of petroleum infrastructure in Libya has been emerged since the early days of hydrocarbons exploration in 1955. The first wildcat well was drilled in 1959 at 17500 b/d in Sirte basin by ESSO Standard Libya Inc., and the first barrel of oil exported from Libya was in October 1961. Further exploration efforts resulted in several oil and gas discoveries during the 1960's and 1970's. Subsequently, most of downstream projects have been established and developed between 1970 and 1990 such as Azzawia refinery and its lubricating oil unit, Ras-Lanuf refinery and petrochemical complex, Brega refinery and petrochemical complex, Tobruk refinery, and Sarir refinery with a combined nameplate capacity of approximately 380,000 b/d, significantly higher than the volume of domestic oil consumption 242,500 b/d in 2005 (OPEC, 2005). Libya aims to increase its producing capacity to 3 Mb/d by 2015. In order to achieve this goal and also to upgrade its oil infrastructure in general, Libya seeks as much as $30 billion in investment over that period (EIA, 2006). Moreover, Libya is considered a highly attractive oil province due to low cost of oil recovery, the high quality of its oil (low sulfur content, lighter and easier to handle than other crudes), its proximity to European markets, and its being developed infrastructure.

4.7.2 Considerable Hydrocarbon Potential

Libya is well endowed with oil and gas resources. At the present time, it becomes Africa's second largest oil producer and among Europe's biggest oil suppliers. However, the search for hydrocarbons potential continues unabated as only around 30 per cent of Libya has been hitherto explored for hydrocarbons (NOC, 2009b). Its proven oil reserves estimated in 2005 to exceed 41 billion barrels (i.e., 3.6% of world total). Natural gas potential reportedly exceeds 1.4 trillion cubic meters with significant development opportunity that could help Libya become a key supplier to Europe in the near future (OPEC, 2005), and it should be stressed that reserve estimates tend to rise over time through greater knowledge from increased exploration and development. Table 4.2 shows the undiscovered hydrocarbon resources in Libya as estimated in 2000 by U.S. Geological Survey.

Resource	F95	F50	F5	Mean
Oil (million barrels)	2,923	7,4 181	15,348	8,271
Gas (million cubic feet)	5,710	15,439	47,174	21,109
F95 represents a 95 percent chance of at least the amount tabulated (other percentiles defined similarly).				

Source: US. Geological Survey, 2000 (World Bank, 2006)

Table (4.2): Estimated Undiscovered Hydrocarbon Resources in Libya

4.7.3 Less Diversified Economy

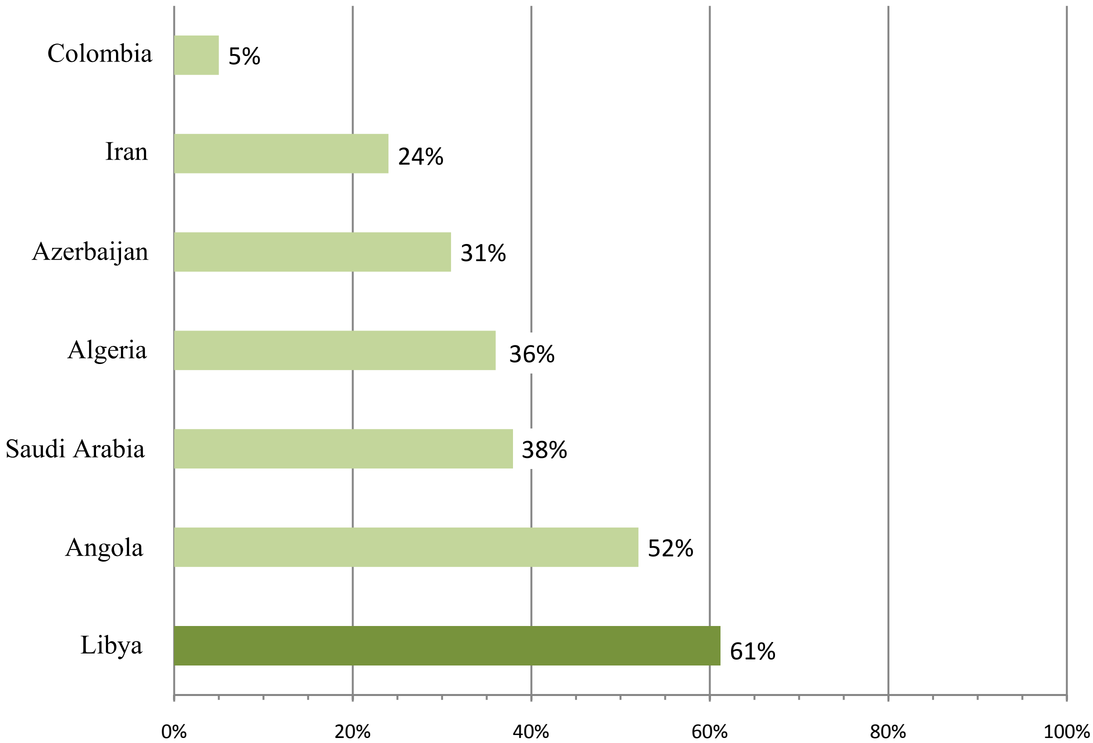
The Libyan economy is highly dominated by hydrocarbon revenues, which in 2005 contribute approximately to 73 percent of nominal GDP, 93 percent of government revenues and 95 percent of export earnings (IMF, 2007). However, with the hydrocarbon sector representing the most significant player in the economy as depicted in table 4.3, Libya appears to be one of the less diversified oil-producing economies in the world and its economic performance has been shaped by changes in oil revenues (World Bank, 2006).

GDP at factor cost	2000	2001	2002	2003	2004	2005
Non-oil sector (%)	60.2	60.8	47.2	38.8	32.9	27.4
Oil sector (%)	39.8	39.2	52.8	61.2	67.1	72.6
Total (%)	100	100	100	100	100	100
Note: Augmentation of Oil sector % GDP during 2000-2005 due to international increase of oil prices.						

Source: Ministry of Planning – Libya, IMF (2006)

Table (4.3): Sectoral Distribution Percentage of Libya GDP at Current Prices (2000-2005)

In 2003, the share of hydrocarbon revenues in Libyan GDP was almost double that of Saudi Arabia and nearly threefold that of Iran, see figure 4.13.



Source: WDI and IMF (World Bank, 2006)

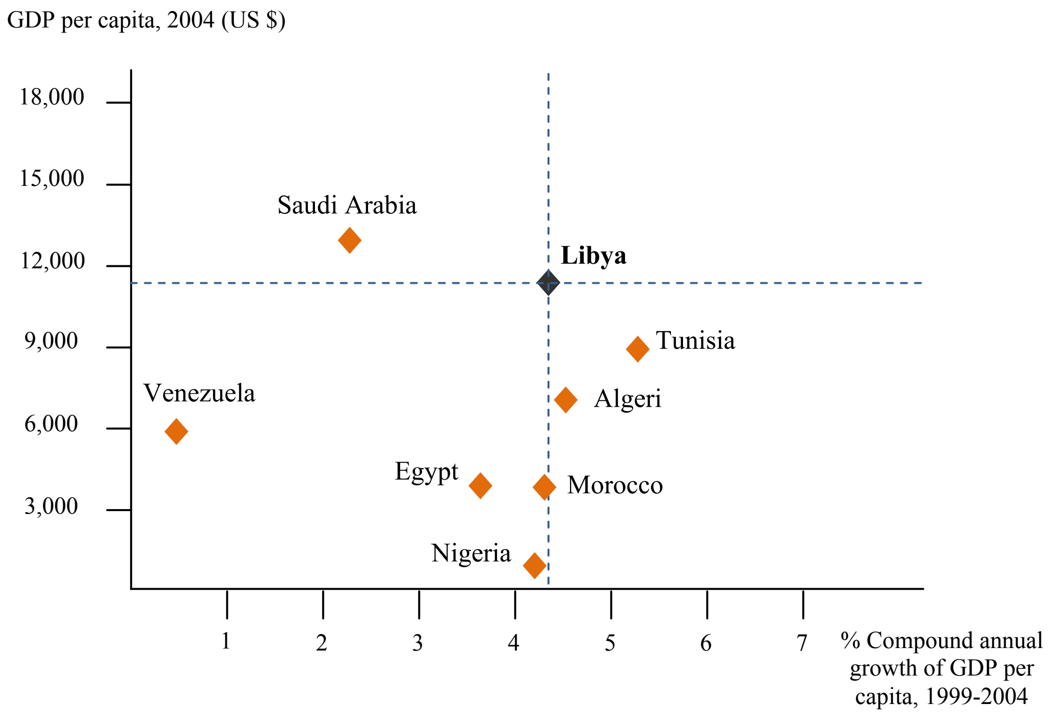
Figure (4.13): Hydrocarbon % GDP of Libya and Comparators in 2003

Thus, investing in technology development across many sectors in Libya including oil and gas sector will dramatically build up national technological capabilities, enhancing competitiveness within productive and services activities, and accordingly help diversify the country's economy as a whole.

4.7.4 Continuous Human Development

Of the poorest countries in the world in the 1950s, Libya now ranks ahead of several oil-producing countries as well as Middle East & North Africa countries (MENA) in terms of GDP per capita (World Bank, 2006), as depicted in figure 4.14.

Additionally, Libya ranked 66 amongst 177 countries in human development index at 0.798, and its education index is 0.86 out of 1.00, while combined gross enrolment ratio for primary, secondary and tertiary schools is 94% (UNDP, 2006b). Furthermore, the total number of labour force in Libyan petroleum sector reaches on March 2007 to 44,861 employees distributed to 93.9 percent of natives and 6.1 percent of expatriates (NOC, 2007c).



Source: IMF, World Bank

Figure (4.14): GDP per capita and Growth for Libya and other Countries

4.7.5 Wide-Ranging Economic Reform

Since the freezing of the UN sanctions in 1999, Libya has been implementing measures to reform and open its economy. Libya needs strong and sustained economic growth to meet the demands of its rapidly growing labour force, which requires high investment in physical and human capital, and an efficient use of the country's resources. This can only be achieved through the implementation of far-reaching market-oriented structural reforms that would enhance the role of the private sector, improve the business climate, and promote economic diversification. Structural reforms continue with the implementation of a wide range of measures. These reforms covered international trade and finance, banking and payments systems, fiscal management and taxation, and data collection (IMF, 2006).

Overall, Libya recently has appropriate business drivers to invest in technology development as a result of many reasons, some of them are: (1) a vast part of its potential hydrocarbons needs to be explored and exploited through numerous technological means, (2) its petroleum technical infrastructure entails upgrading and maintaining to meet future goals, (3) to support technologically the prospective role that might Libya undertake in international oil & gas arena owing to its expected massive reserves, (4) the need to diversify its economy and entering today's knowledge-based economy through building native technological competency that could be exploited in hydrocarbon sector and extended consequently to non-hydrocarbon production sectors, (5) due to its accumulated petroleum expertise gained during the past decades and its good indications of human resources development that can be deployed properly to meet technological change, and eventually (6) the wide-ranging economic reform environment being currently settled in Libya.

Chapter Five

THE RESEARCH METHODOLOGY

5. THE RESEARCH METHODOLOGY

5.1 INTRODUCTION

Research methodology is a specific direction the research will take to solve the underlying problem. Methodology refers, in particular, to the overall approach of the research process from theoretical foundation to practical side of the study. In this context, researchers have to decide how they are going to determine the theoretical underpinning in which the methodology rooted, and how they will tackle the collection and analysis of data or what type of approach they should use to collect and analyze their data. The general approach to plan a research study may be similar across various disciplines, but the specific methods one uses to collect and analyzing data are diverse in accordance with the working area of research. This is because data vary extensively in nature.

This chapter is aimed at demonstrate the methodology used in this study. The subsequent section revealing the basis on which the research paradigm and the logical principles have been selected. The thought process of reasoning the research problem is established in the third section. The fundamental choices are considered in the fourth section to determine the appropriate research approach that matches nature of the research problem. The fifth section addresses methods of data collection and analysis. Design of the measuring instrument is basically elaborated in the sixth section; whiles the final section is devoted to demonstrate the validity and reliability improvement.

5.2 THE RESEARCH PARADIGM

It is quite important in this section to emphasize that realizing the appropriate research paradigm will help the researcher identifying the theoretical basis on which the research methodology rests, recognizing how such paradigm restricts the methodology choice, and help determining, consequently, the entire course of the research project. Collis and Hussey (2003) put forward that there are two main research paradigms; the *"positivistic"* paradigm and the "*phenomenological*" paradigm.

5.2.1 The Positivistic Paradigm

Historically, the positivistic paradigm is based on the approach used in natural science. Such approach seeks facts or causes of a particular phenomenon, with little regard to the subjective state of individuals. Thus, logical reasoning is applied to the research so that precision, objectivity and rigour replace hunches, experience and intuition as the means of investigating research problem. According to positivists, laws provide the basis of explanation, permit the anticipation of phenomena, predict their occurrence and therefore allow them to be controlled. Explanation consists of establishing causal relationships between variables by establishing causal laws and linking them to a deductive or integrated theory.

5.2.2 The Phenomenological Paradigm

The phenomenological paradigm, on the other hand, is concerned with understanding the social realities from the participant's own frame of reference. A reaction to the positivistic paradigm, it is assumed that social reality is within us; therefore the act of investigating reality has an effect on the reality. Considerable regard is paid to the subjective state of individual. This qualitative approach stresses the subjective aspects of human activity by focusing on the meaning, rather than the measurement, of social phenomena. The research methods used under this approach are an array of interpretative techniques which seek to describe, translate and otherwise come to terms with meaning, not the frequency of certain more or less naturally occurring phenomena in the social world (Van Maanen, 1983).

The phenomenological paradigm developed as a result of criticism of the positivistic paradigm. The main criticisms of the positivistic paradigm are: 1) It is impossible to treat people as being separate from their social contexts and they can not be understood without examining the perception they have of their own activities. 2) A highly structured research design imposes certain constraints on the results and may ignore relevant and interesting findings. 3) Researchers are not objective, but part of what they observe. They bring their own interests and values to the research. 4) Capturing complex phenomena in a single measure is, at least, misleading. For example, is it possible to assign a numerical value to a person's intelligence?

Furthermore, Allard-Poesi and Maréchal (2001) have classified more specifically the phenomenological paradigm into "*Interpretativist*" approach and "*Constructivist*" approach.

– *Interpretativist Approach*: The interpretativists' knowledge goal is not to discover reality and the laws underlying it, but to develop an understanding of social realities. This means developing understanding of the culturally shared meanings, the intentions and motives of those involved in creating these social realities, and the context in which these constructions are taking place. In this perspective, the research process is not directed by an external knowledge goal as in the positivist research approach, but consists of developing an understanding of the social reality experienced by the subjects of the study. The research problem, therefore, does not involve examining facts to discover their underlying structure, but understanding a phenomenon from the viewpoint of the individuals involved in its creation in accordance with their own language, representations, motives and intentions.

– *Constructivist Approach*: For the constructivists, knowledge and reality are created by the mind. There is no unique real world that pre-exists independently from human mental activity and language: all observation depends on its observer including data, laws of nature and external objects (Segal, 1990). In this regard, reality is pluralistic, i.e. it can be expressed by a different symbol and language system, but also plastic, i.e. it is shaped to fit the purposeful acts of intentional human agents (Schwandt, 1994). The knowledge sought by constructivists is therefore contextual and relative, and above all instrumental and goal-oriented. Constructivist researchers construct their own reality, starting from and drawing on their own experience in the context in which they act (Von Glaserfeld, 1984). The dynamics and the goal of knowledge construction are always linked to intentions and motives of the researcher, who experiments, acts and seeks to know. Eventually, the knowledge constructed should serve the researcher's contingent goals: it must be operational. It will then be evaluated according to whether it has fulfilled the researcher's objective or not, that is according to a criterion of appropriateness (Le Moigne, 1995). From this perspective, constructing the research problem is to design a goal-oriented project. This project originates in the identification of a need to alter traditional responses to a given context- to change accepted modes of action or of thought. The construction of the research problem takes place gradually as the researcher develops his/her own experience of the research. The project is in fact continually redefined as the researcher interacts with the reality studied (Le Moigne, 1995). Because of this conjectural aspects of the constructivist process of constructing knowledge, the research problem only appears after the researcher has enacted a clear vision of the project and has stabilized his/her own construction reality.

Therefore, it would worthwhile to point out in this context that the interpretativist approach, contrary to other paradigms, is the most fitting paradigm for this study for the following reasons: 1) The research principally aims to develop an evolutionary management framework for technological catching-up which is essentially based on developing an inside understanding of a phenomenon being studied; "*failing of Libyan oil sector to produce technology*". 2) There is a sort of interaction between the subject and object in this study. The reality of phenomenon (object) under investigation is rested on reality experienced by the participants (subject) involved in the survey in terms of Libyan oil organizations, foreign oil companies, petroleum research community, public universities & research institutes, and private companies of technical oil services.

Table 5.1 summarizes the main features of various research paradigms and demonstrates the appropriate paradigm that matches the nature of this study.

MAIN CHARACTERISTICS OF RESEARCH PARADIGMS		
Positivistic Paradigm	**Interpretativist Paradigm**	**Constructivist Paradigm**
– *Nature of reality*: Ontology	– *Nature of reality*: Phenomenology	– *Nature of reality*: Phenomenology
– *Subject-object relationship*: Independence	– *Subject-object relationship*: Interaction	– *Subject-object relationship*: Interaction
– *Research goal*: Discover and explain the structure of reality	– *Research goal*: Understand the significations people attach to social reality, and their motivations and intensions	– *Research goal*: Propose a reality constructed by the researcher
– *Origin of knowledge*:	– *Origin of knowledge*: Empathy	– *Origin of knowledge*:

Observation of reality		Construction
– *Nature of research problem*: Examination of the facts	– *Nature of research problem*: Development of an inside understanding of a phenomenon studied	– *Nature of research problem*: Development of a knowledge project
– Tends to produce quantitative data	– Tends to produce qualitative data	– Tends to produce qualitative data
– Uses large samples	– Uses small samples	– Uses small samples
– Concerned with hypothesis testing	– Concerned with generating theories	– Concerned with generating theories
– Data is highly specific and precise	– Data is rich and subjective	– Data is rich and subjective
– The location is artificial	– The location is natural	– The location is natural
– Reliability is high	– Reliability is Low	– Reliability is Low
– Validity is low	– Validity is High	– Validity is High
– Generalises from sample to population	– Generalises from one setting to another	– Generalises from one setting to another
×	√	×

Source: Extracted from Allard-Poesi & Maréchal (2001) and Collis & Hussey (2003)

Table (5.1): Main Characteristics of Various Research Paradigms

5.3 THE THOUGHT PROCESS

5.3.1 The Research Logical Principles

Charreire and Durieux (2001) elaborate that, knowledge exploration and testing central to the construction of knowledge are both fundamental to management research. Exploration is the process through which the researcher seeks to formulate innovative theoretical propositions, while testing appraises the reality of theoretical conjecture. A researcher's epistemological positioning will affect the choices he/she makes; whether to test or explore. Whereas the process of testing resolutely places research within the positivist paradigm, and the process of exploration has no particular association with any single paradigm. In other words, through exploration researchers satisfy their initial intentions to propose innovative theoretical results – to create new theoretical links between concepts, or to integrate new concepts into a given theoretical field. Testing is the set of operations by which the reality of one or more theoretical elements assessed. Also, testing is used to evaluate the significance of hypothesis, models or theories to a given explanation.

The dichotomy (exploration and test) is justified by the different types of logic that are characteristic of these two processes. To explore, the researcher adopts an approach that is either "*inductive*" or "*abductive*" or both, whereas testing calls for a "*deductive*" method.

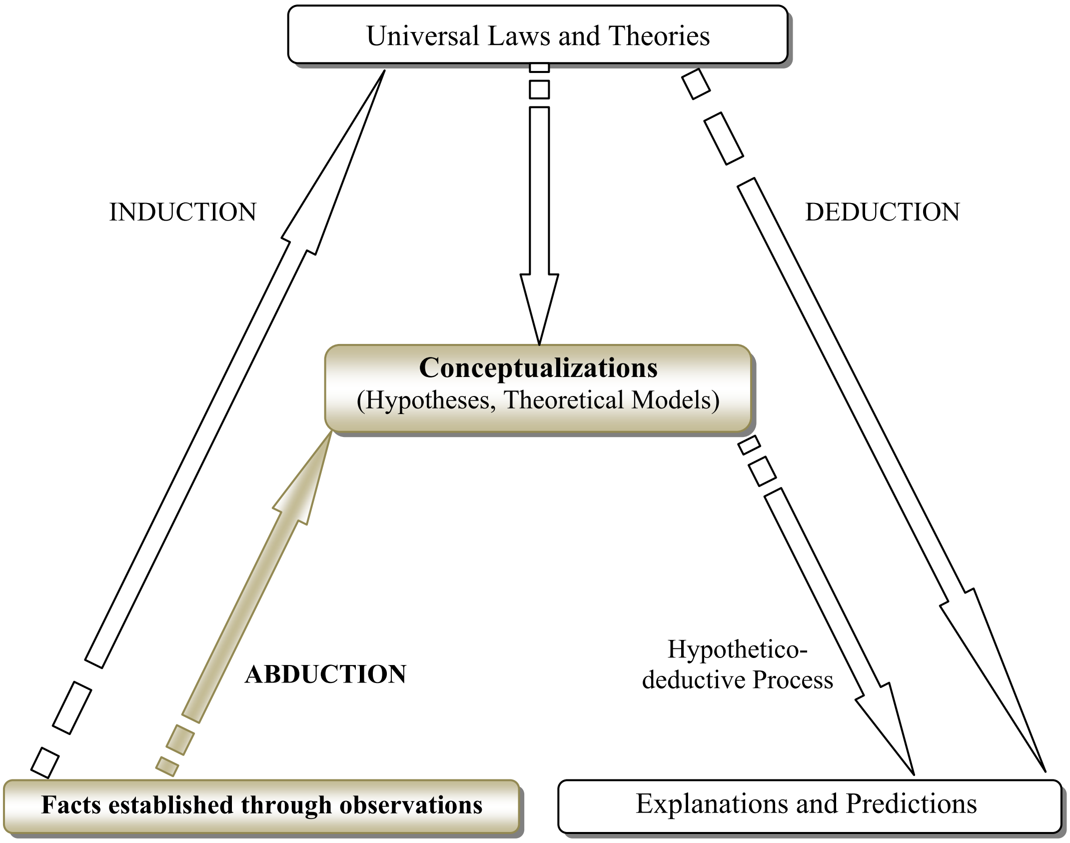
In this sense, table 5.2 differentiates between various logical principles for investigation of knowledge and highlights the appropriate one for this study.

MAIN CHARACTERISTICS OF RESEARCH LOGICAL PRINCIPLES		
Deduction Approach	**Induction Approach**	**Abduction Approach**
– Underpins the hypothesis testing. This consists of elaborating one or more general hypotheses, and then comparing them against a particular reality in order to assess the validity of the hypotheses formulated initially. – Deduction starts from a rule considers a case of this rule and automatically infers a necessary result.	– Defined as the operation of discovering and proving general propositions by which one can infer what is known to be true in a particular case or cases will be true in all cases which resemble the former in certain assignable respects. – Asserts the truth of a general proposition by considering particular cases that support it. – Induction is a logical inference which confers on a discovery an a priori constancy which gives it the status of law.	– It is an inferential process which is opposed to deduction. – Used to propose new theoretical conceptualizations that are valid and robust, and thought through in minute detail. – Abduction confers on an explanatory status which then needs to be tested further if it is to be tightened into a rule or a law.
×	×	√

Source: Extracted from Charreire & Durieux (2001)

Table (5.2): Main Characteristics of Various Logical Principles for Investigating Knowledge

Moreover, figure 5.1 (p.163) demonstrates the logical principles for scientific knowledge investigation.



Source: Adapted from Chalmers (1976) as cited in Charreire & Durieux (2001)

Figure (5.1): Various Logical Principles of Research

5.3.2 Reasoning of Research Problem

Scientific inquiry is described traditionally as a puzzle-solving task which entails clarification through reasoning. In this perspective, the reasoning process of research problem in this study (see figure 5.2, p.164) is designed to take place as follows: 1) The research problem which represents the phenomenon (fact) under consideration has to be clearly defined, for instance, as "*Petroleum technology in Libya is not developed successfully*". 2) An abduction reasoning process to explore the phenomenon and to determine its potential causes necessities analysing the research survey. 3) A tentative explanation of phenomenon in terms of hypothesis should be accordingly formulated. 4) Finally, the tentative hypothesis needs to be tested further, within a scope of future research work, if it is to be tightened into a rule or a law.

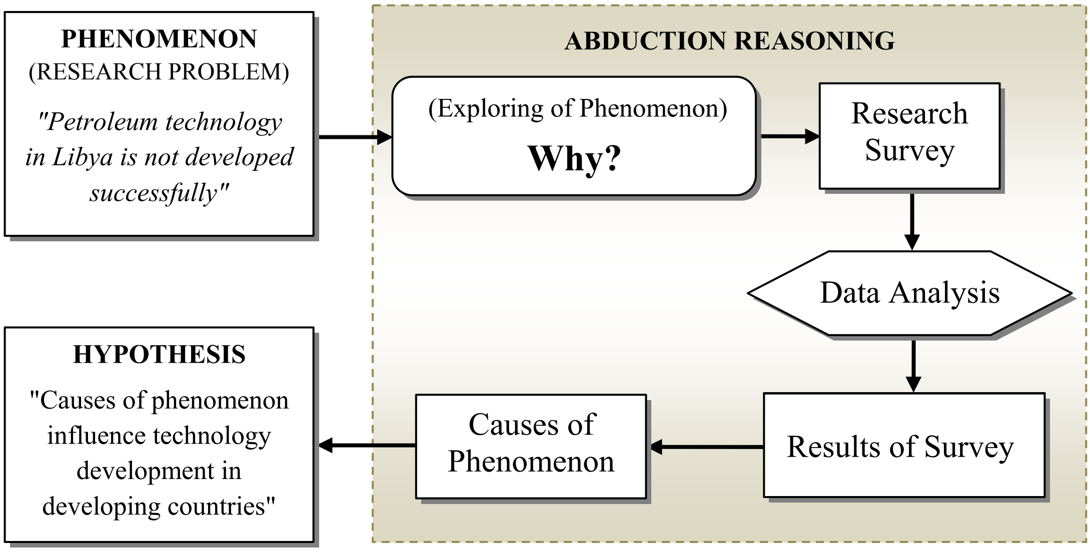


Figure (5.2): The Reasoning Process of Research Problem

5.4 THE RESEARCH APPROACH

One of the fundamental choices researchers have to make is to determine what type of process approach they want to use to solve the research problem. In making such choice, Leedy and Ormrod (2001) mention that the researchers are in fact seeking to recognize two research approaches; *Quantitative* approach and *Qualitative* approach.

5.4.1 The Quantitative Approach

Quantitative research approach is used to answer questions about relationships among measured variables with the purpose of explaining, predicting and controlling phenomena. It is conventional to correlate verification process with a quantitative approach. When researchers direct their work towards verification, they have a clear and definite idea of what they are looking for. The quantitative approach is typically oriented toward testing of theories. The quantitative study usually ends with confirmation or disconfirmation of the hypotheses that were tested. These tentative hypotheses may form the basis of future studies –perhaps quantitative in nature– designed to test the proposed hypotheses. Furthermore, it is generally acknowledged that quantitative approach offers a greater assurance of objectivity than do qualitative approach. The flexibility available to researchers in conducting their research of quantitative approach is highly strict since there is obviously difficulty to modify the research question during the more rigid process that is required by the quantitative approach, taking into account the cost that such a modification would entail (Baumard and Lbert, 2001).

5.4.2 The Qualitative Approach

In contrast, qualitative research is typically used to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participant's point of view. The qualitative study is more likely to end with tentative answers or hypotheses about what was observed. If the researchers are carrying out explorative research typified by theoretical construction, they are often far less sure of what they may find. Therefore, the exploration process is correlated with qualitative approach. According to Erickson (1986) the most distinctive feature of qualitative investigation is its emphasis on interpretation. The researchers must position themselves as interpreters of the field they are studying, even if their own interpretation may be more laboured than that of the research subjects. The qualitative approach, in fact, allows for both the subjectivity of the researcher and that of the subjects at the same time. Furthermore, when a qualitative approach is used, the research question can be changed midway, so that the results are truly drawn from the field (Stake, 1995).

Yet theses approaches are often carried out in different ways, leading to distinctly different research methods. The choice between a qualitative and a quantitative approach seems to be dictated primarily to the orientation of research whether constructing or testing. Table 5.3 presents a summary of differences between quantitative and qualitative approaches and highlights the research approach that satisfies the nature of this study.

DISTINGUISHING CHARACTERISTICS OF RESEARCH APPROACHES	
Quantitative Approach	**Qualitative Approach**
Purpose of the research: – To explain and predict – To confirm and validate	*Purpose of the research*: – To describe and explain – To explore and interpret

– To test theory	– To build theory
Nature of the research process: – Focused – Known variables – Structured guidelines – Static research design – Context-free – Detached view	*Nature of the research process*: – Holistic – Unknown variables – Flexible guidelines – Emergent research design – Context-bound – Personal view
Methods of data collection: – Representative, large samples – Standardized instruments – Relative ease and speed with which the research can be conducted.	*Methods of data collection*: – Informative, small samples – Observations, interviews – Expensive and time consuming but provide a more real basis for analysis and interpretation.
Data analysis: – Deductive analysis	*Data analysis*: – Inductive analysis
Reporting findings: – Numbers – Statistics, aggregated data – Formal voice, scientific style	*Reporting findings*: – Words – Narratives, individual quotes – Personal voice, literary style
×	√

Source: Adapted from Leedy & Ormrod (2001) and Collis & Hussey (2003)

Table (5.3): Main Characteristics of Various Research Approaches

5.5 DATA COLLECTION AND ANALYSIS

5.5.1 Targeting of Populations

Population refers to collection of items (e.g. body of individuals) under consideration for research purposes. Depending on the nature of the research and the size of population being studied, the whole population can be used. In this context, several populations have been entirely targeted in this study because they are physically restricted to limited size of organizations and individuals which can be likely surveyed altogether. These populations are as follows:

– *Population of national petroleum research institutes of public ownership*: This population is represented by the Libyan Petroleum Institute (LPI) as being considered the only research institute in Libyan oil industry and cross nationwide which addresses the activities of petroleum research and development and is above all considered a central body of knowledge for national petroleum industry. This organization is surveyed in order to explore its capability for developing technology through questioning its top-management policy makers by using a self-completion questionnaire. The percentage of response is 100%. This part of survey has taken almost six months to complete successfully.

– *Population of national petroleum companies of public ownership*: This population encompasses twelve national companies of upstream & downstream industry and technical services. These firms have been targeted in order to explore their competence for participating in developing technology through questioning their boards of directors by using a self-completion questionnaire. Seven companies have fully responded. The percentage of response is about 59%. The survey has taken almost ten months to complete.

– *Population of national research community in Libyan petroleum industry*: This population consists of one hundred and three researchers who almost shape the research community of Libyan oil industry. Using an interview-administrated questionnaire, a large part of them has been interviewed in order to facilitate the responses. Around 70% of the research personnel responded successfully. The survey has spanned three months and dedicated to explore the characteristics of business environment for research and development at Libyan oil sector.

– *Population of foreign petroleum companies*: This population comprises thirty four companies of upstream & downstream industry and technical services which representing the key international oil firms working in Libya. This population is targeted to survey the interaction of foreign oil companies with Libyan oil industry towards supporting technology development by means of inward Foreign Direct Investment (FDI). The survey procedure, in this regard, involves questioning the firms' top executive managers by using a self-completion questionnaire. The submission and response process has taken almost eight months where twenty one foreign oil companies have completely responded to the questionnaire. The percentage of response is about 62%.

– *Population of national universities and research institutes of public ownership*: This population represented by four universities and two research institutes which most likely having some kind of collaboration with oil industry. These organizations have been targeted actually to survey the interaction of some national universities & research institutes of public ownership with Libyan oil industry towards developing of petroleum technology. This part of survey has taken five months to complete. Besides, it is devoted mainly to questioning the organizations' scientific committees by using a self-completion questionnaire. Two university and two research institutes have been responded. The percentage of response is about 67%.

– *Population of national companies for oil technical services of private ownership*: The population of fifteen national services oil companies of private sector have been targeted in order to investigate their roles towards petroleum technology development in Libya through realizing the characteristics of interaction between those firms and Libyan oil industry. Almost five months have been devoted to complete this part of survey which essentially directed to interview the companies' top managers by using an interview-administrated questionnaire. Eight companies are responded which represent 54% of entire population.

5.5.2 Sources of Data

There are two main sources of data in this study: 1) Original data which is known as primary data and collected at source under uncontrolled situation by asking questions of survey questionnaire. 2) Secondary data which already exists in numerous kinds of relevant publications such as books, published statistics, annual reports, internal records kept by organizations, etc.

Primary and secondary data are complementing each other at all stages of the research process. If primary data is insufficient, it can be supplemented by secondary data and vice versa. In this sense, figure 5.3 (p.169) demonstrates using of primary and secondary data in this study.

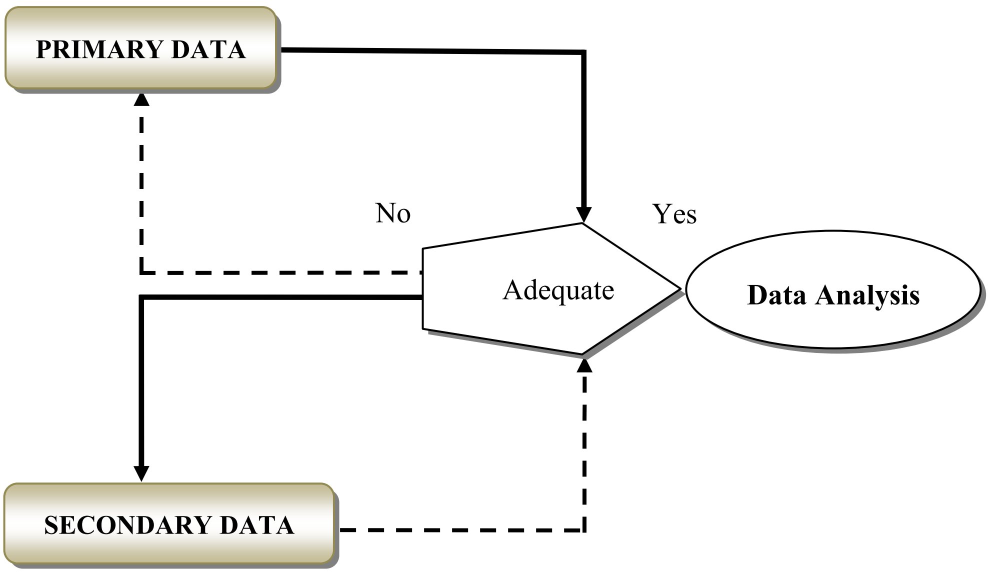


Figure (5.3): Complementary of both Primary and Secondary Data

5.5.3 Method of Data Collection

Data collection method is considered an integral part of the entire research process which is concerned with gathering of data. Such method is not of necessity qualitative (phenomenological) or quantitative (positivistic) in its nature, but by how it is used. If a method is used to collect data on the frequency of occurrence of a particular variable, quantitative data (numerical data) will be obtained, while if collecting data is on the meaning of a certain phenomenon, then qualitative data (nominal data) will be acquired. Some qualitative data collection methods are so closely intertwined with the analysis of the data that is difficult to separate the two processes. Furthermore, whether the research under study is following a broadly phenomenological or positivist paradigm, there will be always a combination of qualitative and quantitative inputs into data generating activities. The balance will depend on the analytical requirements and the overall purpose of research (see Collis & Hussey, 2003).

Thus, table 5.4 (pp.170-173) exhibits the characteristics of main data collection methods and highlights the appropriate data collection method that matches the nature of this study.

MAIN CHARACTERISTICS OF DATA COLLECTION METHODS	SELECTED METHOD
Critical Incident Technique: – It is used in interviews to generate qualitative data. – It is used to gather facts in a rather objective fashion with only a minimum of inferences and interpretation of a more subjective nature. – It encompasses asking some open – ended questions where the intended purpose is clear and effects appear logical. – It is a flexible set of principles which should be modified and adapted according to circumstances. – *Advantage*: It is used when there is a lack of focus or the interviews have difficulty in expressing their opinions. – *Disadvantages*:1) Respondents are being asked to remember a particular event and the reasons for their choice are not evident. 2) There is a danger that respondents may fail to remember important facts to impose a certain logic and coherence which did not exist at the time. 3) The problem of how to analyse the data thus collected.	×
Diaries: – It can be used under either a phenomenological or a positivistic methodology. – It is a daily record of events or thoughts. Participants are asked to record relevant information in diaries over a specific period of time. The information recorded may be quantitative or qualitative. – It offers a method of collecting data from the individual point of view. – *Advantage*: It can be a useful means of gaining sensitive information or an alternative to using direct observation. – *Disadvantages*: 1) Problem of selecting participants who can express themselves well in writing. 2) Problems arisen from the issue of confidentiality. 3) Involves considerable time and efforts. 4) Bias may occur in diary entries. 5) It is difficult to obtain a random sample as the researcher must rely on volunteers. 6) There is always some unreliability in recording.	×
Focus Groups: – It is associated with a phenomenological methodology, and the data generated from this method is qualitative. – It is used to gather data relating to the feelings and opinions of a group of people who involved in a common situation. – The explicit use of this method to produce data and insights that would less accessible without the interaction found in a group of people provides the researcher with rich data. – It is mainly used in market research, but can be useful in the preliminary stages of any study.	×

Interviews: – It is associated with both positivist and phenomenological methodologies. – It is a method of collecting data in which selected participants are asked questions in order to find out what they do, think or feel. – It might be conducted face-to-face, voice-to-voice, screen-to-screen with individuals or groups. – Questions are likely to be open-ended. Semi-structured interview is an appropriate method when: 1) It is necessary to understand the construct that the interviewee uses as basis for his/her opinion and beliefs about a particular matter or situation. 2) It is essential to develop an understanding of the respondent's world. 3) The step-by-step logic of a situation is not clear. 4) The subject matter is highly confidential or commercially sensitive. 5) The interviewee may be reluctant to be truthful about this issue other than confidentially in a one-to-one situation. – *Advantages*: 1) It permits the researcher to ask more complex questions, which is not possible in a questionnaire. Thus further information can be obtained. 2) It permits a higher degree of confidence in the replies than questionnaire responses as it can take account of non-verbal communications such as the attitude and behaviour of the interviewee. 3) Some clear advantages of face-to-face interviewing are the ability to deal with queries about the meaning of questions, to correct a question misleading, to urge responses, and eventually to show stimulus materials of interest. – *Disadvantages*: 1) It can be very time consuming and expensive. 2) There is the issue of confidentiality. 3) In a positivist study, a large number of interviews are needed and this gives rise to the problem of obtaining access to an appropriate sample. 4) The researcher must ensure that each respondent understands the question in the same way. This demands considerable thought and skill in question design. 5) There is the problem of the effect the interviewer has on the process.	×
Observations: – It is associated with both positivist and phenomenological methodologies. – It can take place in a laboratory setting or in a natural setting which is a research environment that would have existed had researchers never studied. – It can be conducted through non-participant and participant observations. The non-participant observation can be carried out by observe the object of study without the researcher being involved by using, for instance, video, still camera or audio recorder. The participant observation can be done when the researcher is fully involved with the participants and the phenomena being researched. – The aim is to provide the researcher with the means of obtaining a detailed understanding of values, motives, and practices of those being observed. – *Disadvantages*: 1) Variables in a natural setting can not be controlled, but by observing the behaviour in two different setting comparisons can be drawn. 2) Problems of ethics, objectivity, visibility, technology for recording what people	×

say or do, boredom, and the impact of researcher has on those observed. 3) Problems of observer bias may arise, such as when one observer interprets an action differently from a colleague.	
Protocol Analysis: – It is more often associated with a phenomenological methodology. – It is usually used to identify the mental processes in problem solving. The aim is to ascertain the way that people behave and think in a particular situation. The researcher gives some form of written problem to a participant who is experienced in that field of study. The participant then solves the problem, but verbally explains the way he/she is tackling it. This allows the researcher to record the process. Sometimes the participant generates further questions and these can form the basis of subsequent analysis and research. – *Advantages*: 1) It offers a tool for the researcher who is interested in how individuals solve business problem such as to examine the decision-making process. 2) It helps to reduce the problem of interviewer bias. 3) The possibility of omitting potentially important areas or aspects is reduced. 4) The technique is open-ended and provides considerable flexibility. – *Disadvantage*: 1) An expensive and meticulous research method that has had its share of growing pains. 2) It tends to be small, involving fewer than a dozen participants. 3) The process of constructing the problem given to the participants is difficult and can be regarded as part of the research process. 4) The researcher must have sufficient knowledge to be able understand and interpret the logic and methods the participants use to arrive at their solutions.	×
Questionnaire: – It is associated with both positivistic and phenomenological methodologies. – It is a list of carefully structured questions, chosen after considerable testing, with a view to eliciting reliable responses from a chosen sample. The aim is to find out what a selected group of participants do, think or feel. – Cost limited the method of distributing the questionnaire and this depends on the size and location of the study. There are many manners to distribute questionnaire, namely: 1) *By Post*: It is commonly used and inexpensive method. Although it is easy to administer, the response rate can be very low. Response rate of 10% or less are not uncommon and this introduces the problem of sample bias. This can be circumvented by introducing short questionnaire and using closed questions. 2) *By Telephone:* It reduces the cost associated with face-to-face interviews. Response rates can be as high as 90%, but the results may be biased towards people who have a telephone or are willing to answer questions in this way. 3) *Face-to-Face:* It is an expensive and time-consuming method. The response rates tend to be high. It is often very useful if sensitive, complex or lengthy questions need to be asked. 4) *Group Distribution*: It is appropriate for one or a few locations of survey being conducted. Group of people are assembled in one room at the same time and the researcher explains the questionnaire to them and answers any queries. It is convenient, low cost technique and high responses collected. 5) *Individual distribution:* It is applied if the sample is situated in one location. However, if	√

properly designed, this method can be very precise in targeting the most appropriate sample. – *Advantage*: It is cheaper and less time-consuming than conducting interviews and very large samples can be taken. – *Disadvantages*: 1) Confidentiality issue. 2) The questionnaire non-response which occurs if all the questionnaires are not returned. 3) Item non-response which occurs if all questions have not been answered.	

Source: Extracted from Collis & Hussey (2003)

Table (5.4): Main Characteristics of Various Data Collection Methods

In this perspective, the questionnaire method has been selected among others to collect data of intended study because of the following reasons: 1) The nature of study is confined to ask some structured questions of particularity to a group of specific experts in order to explore what those people do, think or feel. 2) Large survey questionnaire need to be conducted and complex and lengthy questions need to be asked. 3) This method is easy to administer, cheaper and relatively less time-consuming.

Moreover, the survey questionnaire in this study has been conducted in terms of the following manners:

– *Self-completion Questionnaire*: It has been used rather than other data collection media such as interviewer-administered survey or telephone-administrated survey to particularly explore technology development competence at Libyan Petroleum Institute (LPI) and national oil companies, and to investigate as well the technological interactions of foreign oil companies and national universities and research institutes with Libyan oil industry. This mode of data collection has been used because the author has encountered a sort of difficulty to interview face-to-face all of those top-management respondents and due to relatively long structure of questionnaire being asked necessitates accordingly a long time to answer. Such time in most cases is longer than time assigned to the interview itself. In this sense, the questionnaire has been posted to every intended top-management respondent urging all of them to complete it within a predetermined period of time. A follow up process and reminding calls have been taken place on weekly basis in order to boost up the responses. The purpose of questionnaire and the context in which the questions being posed have been clearly explained for all participants through an attaching covering letter, an explanatory paragraph and giving precise written instructions regarding the way to answer questions.

– *Interviewer-administrated Questionnaire*: It is directed to survey characteristics of research community in Libyan oil sector and to explore the interaction of private national firms of technical oil services with Libyan oil industry towards developing petroleum technology. The main reason behind using this mode of data collection is to encourage the respondent to complete the questionnaire at once without delay. In this mode of data collection, the respondent has been interviewed face-to-face as a few closed questions are asked. The purpose of questionnaire and the context in which the questions being posed have been presented clearly for every involved participant.

5.5.4 Method of Data Analysis

The main challenge to qualitative data analysis is that there is no clear and accepted set of conventions for analysis corresponding to those observed with quantitative data (Robson, 1993). In addition, despite the proliferation of qualitative methodology texts detailing techniques for conducting a qualitative project, the actual process of data analysis remains poorly described (Morse, 1994).

Hence, the process of data analysis in this study is deliberately developed in accordance with the following sequence:

– *Grouping of Data:* Data is grouped in groups to facilitate, and provide the best partitioning for, data analysis process. Data grouping in this study is predetermined in terms of closed question multiple choices, whereas every investigated set of variables has been grouped under one identified concept; for instance, the question being asked on the concept of modelling technological development is designed to encompass the following options: science-push model, market-pull model, network model, or interactive model.

– *Quantifying of Data:* It is a way of systematically converting text to numerical variables for quantitative data analysis by assigning numbers to answers so the responses can be categorized into a limited number of classes. To quantify data, *"coding technique"* can be used to help the researchers reducing several hundreds of replies to a few classes containing the critical information needed for analysis. In this regard, a specific coding technique has been established in this study to convert the qualitative responses into quantitative data in favour of testing hypotheses and showing relationships.

– *Assessment of Internal Consistency Reliability:* Summated measurement scales are usually used in survey instruments to investigate underlying constructs of interrelated items that the researcher aims to measure. Assessment of internal consistency reliability is essential to test how consistent the results are for different items for the same construct. In this sense, Cronbach's Alpha test tends to be the most widely used estimate to assessing the internal consistency reliability of a set of different variables within each single construct in the questionnaire. Cronbach's Alpha is mathematically equivalent to the average of all possible split-half correlations from the same sample. Cronbach's Alpha coefficient ranges from 0.00 to 1.00. For instance, if the coefficient for a set of variables is 0.85, it means that the test is 85% reliable (see Cronbach, 1951, 1970; Nunnaly, 1978; Shrout and Fleiss, 1979; Raykov, 1998).

– *Univariate Analysis of Variables:* The kind of analysis in this context addresses *"univariate"* data analysis, and aims to conduct: 1) An exploratory data analysis by using techniques of descriptive statistics to summarise, describe or display data through presenting frequencies, measuring central tendency, and measuring dispersion. 2) A confirmatory data analysis, which involves using data collected from responses to draw conclusions about the entire populations. This entails using techniques of inferential statistics.

– *Exploring Differences and Associations of Variables:* Data consists of many variables, which are known as *"multivariate"* data, may require investigating a possible differences or associations (relationships) between theses variables in order to underpin some conclusions and conceptual foundations of interest. Exploring differences would be carried out through some statistical methods in terms of *"parametric*" or *"nonparametric"* techniques based on the nature of data collected (see appendix B), whiles investigating of associations can be ascertained through *"correlation"* technique. If such associations exist, then they would be preferably expressed in mathematical models through *"regression"* techniques.

Figure 5.4 shows the process of data analysis used in this study.

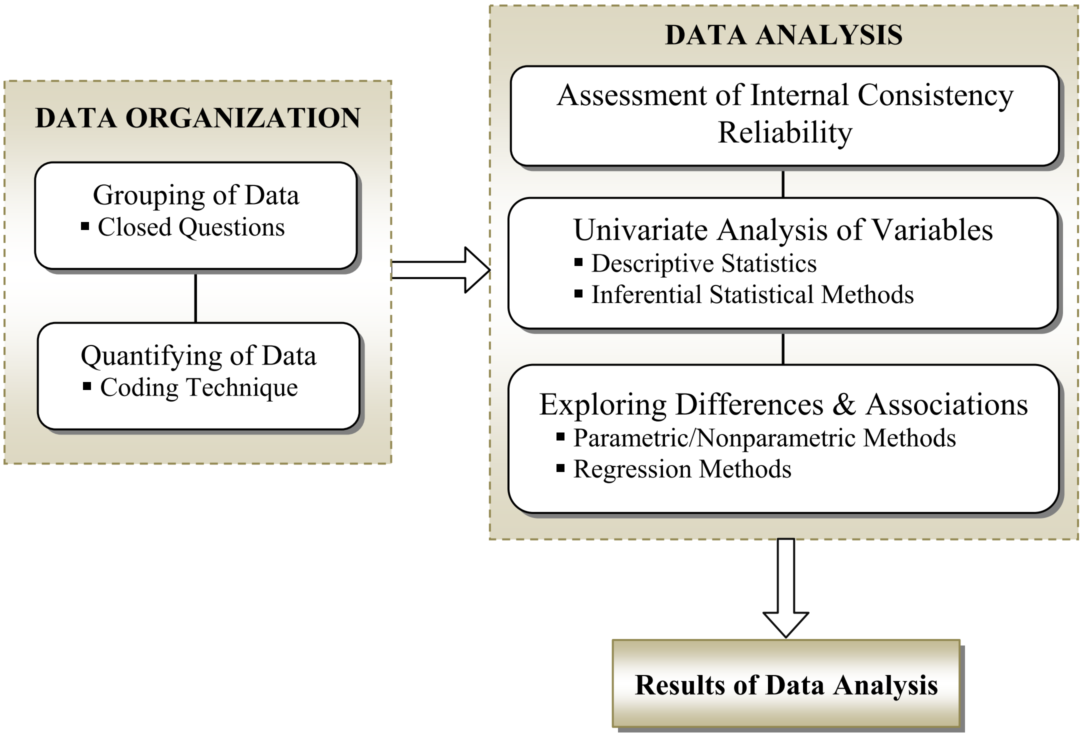


Figure (5.4): The Process of Data Analysis

Moreover, the data sets under study have necessitated the use of statistical software packages such as *"SPSS" and "MS Excel"* in order for conducting the various types of data analysis.

5.5.5 Results Study Approach

Determining the research findings is based on study of obtained results. To do so, one should demonstrate the following issues:1) Strengths and weaknesses of technological development system in Libyan oil sector by using the empirical assessment of technological development essentials as expressed by the entire respondents view (i.e. very high, low, strongly agree, etc) along with the use of some secondary data in relation to technological competence of interest. 2) Areas of concern which will lead to some corrective activities those constitute the postulate management framework of technology development. 3) Causes of phenomenon under consideration.

Figure 5.5 depicts the approach of results study.

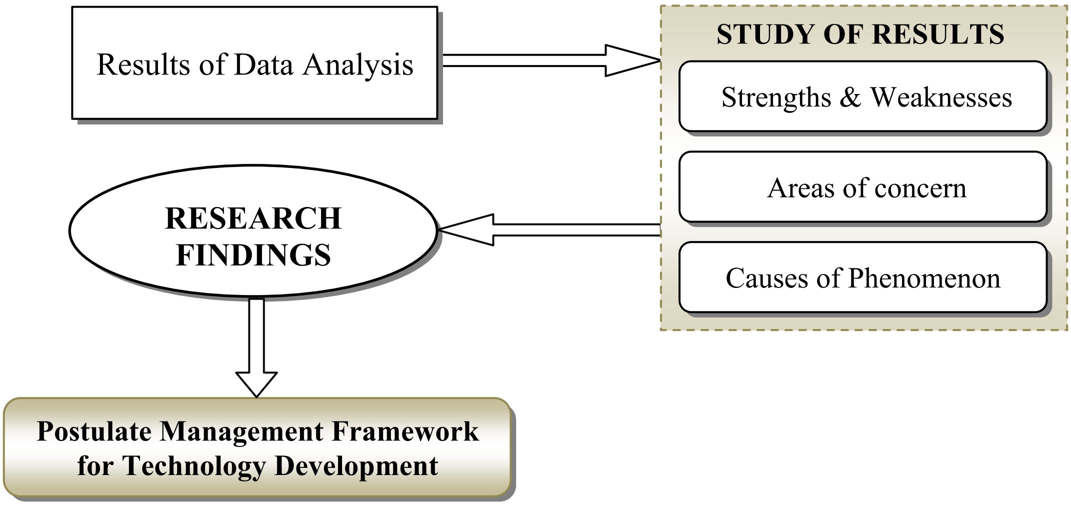


Figure (5.5): The Approach of Results Study

5.6 DESIGN OF MEASURING INSTRUMENT

Designing a questionnaire to survey realities begins with a clear understanding of what it is going to measure, and why. In describing the design process, Floyd and Fowler (1984) argue that:

> *"Designing a good questionnaire involves selecting the questions needed to meet the research objectives, testing them to make sure they can be asked and answered as planned, then putting them into a form to maximize the ease with which respondents and interviewers can do their jobs ... A prerequisite to designing a good questionnaire is deciding what is to be measured. That may seem simple and self-evident, but it is a step that often is overlooked to the detriment of the questionnaire and the study"* (McNair and Leibfried, 1992, p.294).

In this study, the research methodology is in essence based on a multifaceted questionnaire survey (see chapter one, section 1.5.3, pp. 12-13), which is established and conducted using a well- defined approach. Design of research questionnaire is demonstrated in the subsequent sections.

5.6.1 The Measured Variables*:*

Determining of questionnaire dimensions and structure entails recognizing what is to be measured. Thus, the key objectives of intended survey is to measure effectively the following variables: 1) Technological capability of Libyan oil sector for developing technology through investigating characteristics of technological competence, issues critical to developing technology, employment structure, expenditure distribution, and the way of funding. 2) Technological interaction between the key players in Libyan oil sector such as the "*Triple-Helix*" relationships (university-industry-government). 3) Influence of inward foreign direct investment on developing petroleum technology. 4) Technological team competency and characteristics of research environment in Libyan oil sector.

5.6.2 Design of Questions

The significance of incorporating some features during designing the questions will enhance the obtained results and assist in the later analysis of the received responses. Therefore, the following precautions have been taken substantially into account when designing the survey questions of this study to ensure extracting successfully the research primary data.

- Questions should be designed with care to ensure that each respondent will understand the question in the same way, and that every respondent is asked the questions in exactly the same way as the others.

- Questions should be formulated on how the pertinent data are to be analyzed, so that the information collected can be analyzed in the way that is required.

- Questions should be: 1) Written in simple words, clear language, and with no jargons, vague and descriptive words such as large and small. 2) Presented in a logical order, often moving from general to specific topics. This is typically known as "*funnelling*". 3) Kept away from leading or value–laden questions which imply what the required answer might be. 4) Avoiding provoke the participants into giving an opinion where in fact they do not hold one. 5) Not containing offensive or insensitive enquires which could cause embarrassment. 6) Evading ask the participants to perform calculations.

– To weighing up the respondent's creditability in answering questions, the questionnaire should include questions which serve as cross-checks on the answer to other questions.

– The participants should be enabled to give more discriminating responses and state if they have no opinion by providing them with some form of rating scale such as the "*Likert"* scale. This allows obtaining numerical values from qualitative data.

– To prevent the participants from setting up emotional blocks to some questions, questions should be designed to ensure that both positive and negative items appear and that the less extreme statements are first in order. To circumvent *"response acquiescence"* (tendency of participants to agree rather disagree), positive and negative questions must be mixed to keep respondents thinking of their answers.

In addition, questions can be asked in many dissimilar formats. Different types of questions are appropriate for different purposes. Table 5.5 classifies the different question types and suggests the appropriate type for this research survey.

MAIN CHARACTERISTICS OF QUESTION TYPES	
Open/Spontaneous Question	Closed/Prompted Question
– The range of possible answers is not suggested in the question. The respondents are expected to answer in their own words. Such type of questions can be difficult to analyze. – The objective is to identify the full range of responses given by all respondents. It is commonly used to explore attitudes and awareness, and when the researcher wishes to know the precise phraseology (terminology) that people use to respond to the question. – It is used when the researcher can not predict what the responses might be, or it is dangerous to do so. – One of its main difficulties is that the amount of effort that respondents are prepared to make various answers depending on how interested they are in the subject and on the medium of the interview. Open questions may deter busy respondent from replying to the	– The respondent is asked to choose from a number of predetermined set of answers. – Closed/prompted question is generally preferable in large surveys as reduces the variability of response, easy to administer and cheap to process. It is usually easy to analyze, since the range of potential answers is limited. – It is frequently used to measure behaviour. – Prompting with a set of options tells the researcher what people know or recognize, rather than what is front-of-mind. – It helps people to recall actions and behaviour and to express their answers in the framework structured by the researcher in a desirable manner. – Factual question is likely to be closed question. For collecting factual data closed

questionnaire. – Spontaneous responses rarely tell the researcher the complete picture regarding what the respondent knows or feels, but only what is front-of-mind. However, most people find it difficult to articulate every thing that they know or feel about a subject, or they may forget that they know something, or they have given one answer and are not prepared to make any further effort to think additional answers. – Open questions require a stronger grasp of vocabulary and greater ability to frame responses than do closed questions. – Any open question always seeks a spontaneous, which is not prompted response.	questions are very convenient. – It is better to use when there is a clear idea of the respondent's frame of reference, the respondent's level of information is predictable, and the topic of questioning is within the respondent's experience. – Experience has shown that closed question typically requires less motivation and answering it is less threatening to respondents. – In closed/prompt question the list of choices should be exhaustive, where more attention must be paid in favour of identifying the most likely choices in order to avoid missing of other possible options. – Any prompted question is a closed question.
×	√

Source: Extracted from Brace (2004), Collis & Hussey (2003) and Cooper & Schindler (2006)

Table (5.5): Main Characteristics of Various Question Types

Moreover, the characteristics of respondents, the nature of the topic(s) being studied and the type of data needed are all dictate the appropriate question type. In this sense, closed or prompted type of question has been selectively used to investigate reality in this study for theses reasons: 1) It matches the nature of topic which aims to measure the technological behaviour of some organizations and individuals. 2) The respondent's frame of reference and level of information are clearly identified and the topic being investigated is already experienced by the respondents. 3) The survey of interest is considered large in size. This in turn necessitates using closed questions so as to reduce the variability of responses. 4) This type of questions has many advantages that stimulate the author to select it such as easy to administer, cheap to process, easy to analyze and requires less motivation to answer.

5.6.3 Types of Measurement Scales

It is important for the questionnaire writer to recognize which type of measurement scales is being used for each question in order to recording and describing data, and to determine method of data analysis that can be implemented accordingly. Table 5.6 shows the four types of measurement scales which usually measure responses, and demonstrates which of them typify the research questionnaire of interest.

<table>
<tr><th colspan="2">MAIN CHARACTERISTICS OF MEASUREMENT SCALES</th></tr>
<tr><th>Nominal Scale</th><th>Ordinal Scale</th></tr>
<tr><td>– Permits only the classification of data, which will allow the researcher to make statements of equality or differences, but nothing else.
– Responses are classified into one category or another.
– Categories should exhaustive and mutually exclusive.
– Few statistics such as the "mode" might be applied to data collected from this scale.
– Examples; gender (male, female), seniority (junior, senior), etc.</td><td>– Usually found in questionnaire as ranking scales.
– Respondents are asked to put nominal categories in order according to a specific criterion mentioned in the question.
– Ranking puts the nominal data into the appropriate order, but tells nothing about the distance between the categories.
– Since the "arithmetic mean" can not be calculated with data obtained from this scale, the use of many other statistics is also excluded.
– Examples; performance rate (very well, medium, poor), etc.</td></tr>
<tr><td>√</td><td>√</td></tr>
<tr><th>Interval Scale</th><th>Ratio Scale</th></tr>
<tr><td>– Having all characteristics of both nominal and ordinal scales, plus providing information about degree of differences between data items within a set or group.
– Such scales are used in order to determine the relative strength of relationships between items.
– Advantage of this scale is that the researcher can tell whether item is liked or disliked.
– Allows mean scores and standard deviations to be calculated across the sample for each item.
– Includes "semantic differential" scale and "Likert" scale.</td><td>– A particular type of interval scale. The distance between each point on a ratio scale is constant, but the zero point has a meaning, such that the ratio between any two scores also has a meaning.
– With allocation of appropriate scores to each point, or average values to each range, one can calculate mean values and standard deviations for the sample, and carry out statistical tests.
– Ratio scale represents the actual amounts of a variable.
– Examples; weight, height, distance, area, money values, population counts, return rates, productivity rates and amounts of time.</td></tr>
<tr><td>√</td><td>√</td></tr>
</table>

Source: Extracted from Brace (2004), Collis & Hussey (2003) and Cooper & Schindler (2006)

Table (5.6): Main Characteristics of Various Measurement Scales

5.6.4 Piloting of Measuring Instrument

A questionnaire (measuring instrument) being prepared, to meet a set of specific objectives, is rarely right at the first attempt. It is always advisable to pre-test the questionnaire before the survey takes place in real execution. It needs revising and testing until all concerned are happy that they have the best questionnaire that they can use successfully. Failure to pilot the questionnaire represents a serious risk to the success of the survey. With respect to this study, an informal piloting to the questionnaire under consideration has been carried out by a number of colleagues who are familiar with research techniques to address the following points: 1) Do the questions of questionnaire sound right? 2) Do the respondents understand the questions? 3) Does the questionnaire contain any ambiguous or misleading questions, double-barrelled questions, and loaded or leading questions? 4) Can the respondents answer the questions? 5) Does the questionnaire have any sensitive questions that may threaten or embarrassing the participants? 6) Have the questions been written in clear and simple language rather than jargons, and in words familiar to the respondents? 7) Can the respondents understand the routing instructions and footnotes in the questionnaire? 8) Does the questionnaire have a logical sequence? 9) How long does the questionnaire take to be filled in? Have mistakes been made? 10) Do the respondents feel comfortable with the questionnaire format?

During that piloting test some changes have been made in the questionnaire such as : 1) adding more footnotes wherever needed in all parts of questionnaire to explain some related terms within the questions, 2) adding the expression "*national collaboration*" within all scale of questions that contain types of collaboration, 3) adding the expression "*to be available*" in some scale of questions to explore future intent of respondents, 4) giving each questionnaire part different colour in order to organizing the handling of questionnaire, 5) rearranging the sequence of sub-variables of R&D facilities question (in part one & part two of questionnaire) from arbitrary arrangement into a deliberate arrangement in order to divide the structure of theses facilities into physical facilities and intellectual facilities, 6) rewriting the statements of some questions in order to be quite realized, 7) fixing few spelling mistakes, and 8) changing font size of some headings and statements in order to be more suitable for reading.

5.7 VALIDITY AND RELIABILITY IMPROVEMENT

5.7.1 Principles of Improving Validity and Reliability

One of the main questions researchers accustomed to ask is how their research can be both precise and handy to other researchers. To what extent can their results contribute to the field of knowledge in which they work? To answer these questions researchers have to assess their work in relation to *validity* and *reliability* notions. In this perspective, Collis and Hussey (2003) defined reliability as:

> *"Being able to obtain the same results if the research were to be repeated by another researcher"*, and validity as *"the extent to which the research findings accurately represent what is really happening in the situation"* (p.354 & p. 357).

To improve the validity and reliability of qualitative researches, some essential principles, which should be taken into account, have been extracted and adapted from Drucker-Godard et al. (2001), namely:

– *Measurement Errors*: In the social sciences, measurement can be defined as the process that enables us to establish a relationship between theoretical concept and empirical indicators (Carmines and Zeller, 1990). One of the main precautions of researchers in this respect is to verify that the data they plan to collect in the field relates as closely as possible to the reality they hope to study. Numerous occasions for error are likely to arise, making every method of measuring phenomena or the subject being observed more difficult. These errors may include; respondents giving false information; tired observers transcribing their observations badly; changes in attitudes of respondents between two survey occasions; or error in the process of transforming qualitative data into quantitative data. It is therefore essential to ensure that empirical indicators (i.e. field data) are comparable to the measurements employed in order to provide the best possible representation of the phenomenon being investigated. This in turn makes it necessary to address the process by which this measurement has been obtained, or to demonstrate that the measuring instrument used enables the researchers to obtain reliable and valid measurements.

– *Valid and Reliable Measuring Instrument*: To be valid, a measuring instrument must on the one hand measure what it is expected to measure, and on the other hand give exact measures of the studied object. To be reliable, the instrument must allow different observers to measure the same subject with the same instrument and arrive at the same results, or permit an observer to use the same instrument to arrive at similar measures of the same subject at different times.

– *Scale of Validity and Reliability*: The validity of measuring instrument just as much as the reliability is expressed in degrees (more or less valid, more or less reliable) and not in absolute terms (valid or not valid, reliable or not reliable). We have to consider in this context that there is an essential difference, however, in that we test quantitative research to *assess* its validity and reliability, whereas with qualitative research, rather than testing, we take precautions to improve validity and reliability.

– *Measuring Instrument Implication*: For measuring instruments used in qualitative research, Miles and Huberman (1984) point out:

> *"Continuously revising instruments puts qualitative research at odds with survey research; where instrument stability (for example, test-retest reliability) is required to assure reliable measurement. This means that; in qualitative research issues of instrument validity and reliability ride largely on the skills of the researcher"(p.46).*

– *Interview Reliability*: In the case of directive interviews, interview reliability can be enhanced by ensuring that all the interviewees understand the questions in the same way, and that the replies can be coded unambiguously. For this reason, it is necessary to pre-test questionnaires, to train interviewers and to verify inter-coder reliability for any open questions.

– *Interview Validity*: In discussing qualitative research, Miles and Huberman (1984) assert that "the problem is that there are no canons, decision rules, algorithms, or even any agreed upon heuristics in qualitative research, to indicate whether findings are valid". Although certain precautions exist that are designed to reduce errors or possible biases, but the subject of the validity of interviews remains debatable, raising the question of whether researchers should give priority to the accuracy of their measurement or to the richness of the knowledge obtained (Dyer and Wilkins, 1991).

– *Internal Validity*: Internal validity consists in being sure of the pertinences and internal coherence of the results produced by a study; researchers must ask to what degree their inferences are correct, and whether or not rival explanations are possible. Testing internal validity is designed to evaluate the veracity of the connections established by researchers in their analysis. Yin (1989) presents a number of tactics to strength internal validity extended to all qualitative research as follows: 1) Researchers should test rival hypothesis and compare the empirical patterns that are revealed with those of existing theoretical propositions. In this way, researchers can assess whether the relationship they established between events is correct, and that no other explanation exists. 2) It is then necessary to describe and explain, in detail, the analysis strategy and the tools used in the analysis. Such careful explanation increases the transparency of the process through which results are developed, or at least makes this process available for criticism. 3) Finally, it is always recommended to try to saturate the observational field (to continue data collection until the data brings no new information and the marginal information collected does not cast any doubt on the construct design). A sufficiently large amount of data helps to ensure the soundness of the data collection process. Miles and Huberman (1984) added another precaution involves seeking out contradictory evidence through actively seeking out factors that may invalidate the theory the researcher maintains as true. Once a researcher has established a preliminary conclusion, he/she must ask whether there is any evidence that contradicts this conclusion or is incompatible with it.

– *Research Reliability*: The reliability of qualitative research depends partly on the reliability of the measuring instrument. However, the interaction between the researcher and the observational field and the role of the researcher in administering the measuring instrument have a greater impact on research reliability in the case of qualitative research than quantitative, by reason of the very nature of the measuring instruments used in qualitative research. To improve the reliability of a qualitative research, researchers must pay particular attention to: 1) Writing concise instructions if qualitative measuring instruments are to be used by several people or at different times. 2) Explain how to use the instrument. 3) Explain how to understand questions that may be posed if respondents want further explanation before replying. 4)

Describe how to select people to be questioned. 5) Explain how to take notes (e.g. extensive or pre-coded) on the interviewee's replies. 6) Describing the entire research process employed, particularly in the phases which relate to condensing, and analyzing the collected data. These instructions can take different forms; such as a manual for the observer in studied observational field, or as notes accompanying a guide to the interviewing technique, explaining the contents of the questionnaire and how it is to be administered. Carrying out a pre-test can be appropriate occasion for developing these guidelines.

– *External Validity*: To assess the external validity of a research project one should examine the possibilities and conditions for generalizing and transferring the model to other sites. The potential to generalize from research results is a concern that is more familiar to researchers who apply a quantitative methodology than to those who use qualitative methods. The external validity of a study depends essentially on the external validity of the measuring instrument used in the case of quantitative research, and of the research procedure itself in the case of qualitative research. It is, however, important to point out that, researchers will be far better able to ensure the external validity of their research if they take a hard look at the particularities of their observational field from the outset. In particular, researchers can include certain control variable in their measuring instrument, from its conception, to delimit and accurately characterize the population they are studying. By doing so they will improve the level of external validity of the results they obtained on completion of the study. Besides, two aspects of the qualitative research procedure need to be examined in more detail as they have a direct bearing on the external validity of the research; the method used to select the observational field, and the method used to analyze the collected data.

5.7.2 Precautions to Improving Validity and Reliability

Hence, based largely on most principles mentioned earlier, some vital precautions have been considered during research planning and execution to improve the validity and reliability of this study by means of these steps:

– Ensuring that the data collected are directly related to the reality being studied. This was done through emphasizing that the concepts being investigated via questionnaires (measuring instrument) are quietly pertained to; principles, fundamentals and theories of innovation and technology management at sectoral level as pointed up in the relevant literatures; and to particularities of petroleum industry on the other hand.

– Avoiding measurement errors, such as respondents giving false information, was made through selecting appropriate respondents in terms of high-rank policy makers who are in position of responsibility and aware of all management activities, and through designing the questions to be asked in a manner that gives an idea about honesty of respondent in answering a particular enquiry.

– The measuring instrument should permit to arrive at similar results at different measurement events through designing the questionnaire in order to be fairly understood and in a way to be easily replicated with no vague or misleading questions. To verify this, a pre-test procedure was taken place successfully on the questionnaire prior to actual effecting.

– To improve the internal validity of study, a sort of confidence in the truth of the findings has been established through seeking out no contradictory evidence, hitherto, to results of this study either in all reviewed publications or common sensibly. Besides, the analysis strategy in this study and the tools used in that analysis were clearly explained. Designing the questionnaire in a comprehensive structure, to investigate all essential subjects, saturated the observational field with a large amount of collected data.

– To improve the reliability of study, some precautions were carried out such as describing clearly the entire research methodology including the research process, design of survey and method of collecting data, and a concisely instructions of using the questionnaire as well as to the point description concerning objectives of study were attached during sending self-completion questionnaire and introduced to questioned people within interviews.

– The external validity of a particular study can be considered by looking at possibilities and conditions to generalize and transfer its results to other sites. In this sense, the results of this study can enhance generalizing and transferring the postulate management framework of developing technology at sectoral level to other situations in developing countries either through considering the target population in this study is being segment of or representing, to some extent, the whole population of petroleum sector in developing countries based on similarity of characteristics, or through considering the case study of Libyan oil sector is a beneficial study that could complement other case studies which may take place in many developing countries in terms of future work towards building up a generic technology framework suitable to all developing nations.

5.7.3 Internal Consistency Reliability

Internal consistency is typically a measure based on the correlations between different items on the same test (or the same subscale on a larger test). It measures whether several items that propose to measure the same general construct produce similar scores. For example, if a respondent expressed agreement with the statements "I like to ride bicycles" and "I've enjoyed riding bicycles in the past", and disagreement with the statement "I hate bicycles", this would be indicative of good internal consistency of the test (Wikipedia, 2008a).

Internal consistency is usually measured with Cronbach's alpha, a statistic calculated from the pair wise correlations between items. Internal consistency ranges between zero and one. A commonly-accepted rule of thumb is that an α of 0.6-0.7 indicates acceptable reliability, and 0.8 or higher indicates good reliability. High reliabilities (0.95 or higher) are not necessarily desirable, as this indicates that the items may be entirely redundant. The goal in designing a reliable instrument is for scores on similar items to be related (internally consistent), but for each to contribute some unique information as well. An alternative way of thinking about internal consistency, however, is that it is the extent to which all of the items of a test measure the same latent variable (Wikipedia, 2008a).

Cronbach's α is defined as: $\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma_{Y_i}^2}{\sigma_X^2}\right)$

Where N is the number of components (items or test lets), σ_X^2 is the variance of the observed total test scores for the current sample, and $\sigma_{Y_i}^2$ is the variance of component i for the current sample.

Alternatively, the standardized Cronbach's α can also be defined as:

$$\alpha = \frac{N.\bar{c}}{(\bar{\vartheta} + (N-1).\ \bar{c}\ )}$$

Where N is the number of components (items or test lets), $\bar{\vartheta}$ equals the average variance for the current sample and $\bar{c}$ is the average of all covariances between the components across the current sample (Wikipedia, 2008b).

One can see from this formula that if you increase the number of items, you increase Cronbach's alpha. Additionally, if the average inter-item correlation is low, alpha will be low. As the average inter-item correlation increases, Cronbach's alpha increases as well.

Cronbach's alpha will generally increase as the inter-correlations among test items increase, and is thus known as an internal consistency estimate of reliability of test scores. Because inter-correlations among test items are maximized when all items measure the same construct, Cronbach's alpha is widely believed to indirectly indicate the degree to which a set of items measures a single unidimensional latent construct. As a result, alpha is most appropriately used when the items measure different substantive areas within a single construct (as being the case of this study). When the set of items measures more than one construct; coefficient omega hierarchical is more appropriate (Zinbarg, Revelle, Yovel & Li, 2005).

5.8 CONCLUSIONS

- The interpretativist approach is the most fitting paradigm for this research work which aims principally to developing an inside understanding of a phenomenon being studied; "*failing of Libyan oil industry to produce technology*".

- The abduct approach is considered the most appropriate research logical principle for this study which tends to exploring not to testing the reality under investigation.

- The qualitative approach is selected to be used in this study to answer questions about relationships among measured variables with the purpose of explaining and controlling the phenomenon being studied.

- Several populations have been targeted to be investigated in this study, namely: 1) Population of national petroleum research institutes of public ownership. 2)

Population of national petroleum companies of public ownership. 3) Population of national research community in Libyan petroleum industry. 4) Population of foreign petroleum companies operating in Libya. 5) Population of national universities and research institutes of public ownership. 6) Population of national companies for oil technical services of private ownership.

- Primary and secondary data are used throughout this research to complement each other. If primary data is insufficient it can be supplemented by secondary data and vice versa.

- Questionnaire is the main data collection method in this study as it is associated with both positivistic and phenomenological methodologies. It is a list of carefully structured questions, chosen after considerable testing with a view to eliciting reliable responses from a chosen sample. It aims to find out what a selected group of participants do, think or feel. The survey questionnaire in this study has been conducted in terms of *self-completion questionnaire* and *interviewer-administrated questionnaire*.

- The process of data analysis in this study is deliberately developed in accordance with the following sequence: 1) Grouping of data. 2) Quantifying of data. 3) Assessment of internal consistency reliability. 4) Univariate analysis of variables. 5) Exploring differences and associations of variables.

- Closed or prompted type of question has been selected to investigate reality in this study for some reasons, namely: 1) It matches the nature of topic under investigation which aims to measure the technological behaviour of some organizations and individuals. 2) The respondent's frame of reference and level of information are clearly identified and the topic being investigated is already experienced by the respondents. 3) The survey of interest is considered large in size. This in turn necessitates using closed questions so as to reduce the variability of responses. 4) This type of questions is easy to administer, cheap to process, easy to analyze and requires less motivation to answer.

- During the research planning and execution some vital precautions have been considered to improve the validity and reliability of this study.

Chapter Six

DATA ANALYSIS AND RESEARCH FINDINGS

6. DATA ANALYSIS AND RESEARCH FINDINGS

6.1 INTRODUCTION

Data analysis undoubtedly plays a considerable role in formulating research findings. It is in essence a process of gathering, modelling and transforming data with the aim of revealing useful information and suggesting conclusions about the research problem being investigated. In addition, data analysis has multiple facets and approaches, and comprises a variety of methods in science different domains and business research area.

This chapter commences with examining the internal consistency reliability of constructs used in the data analysis by means of Cronbach's Alpha coefficient technique. Univariate analysis of data variables will take place in the third section in terms of descriptive statistics analysis to measure central tendency and dispersion of variables, as well as exploratory data analysis to test hypothesis and determine confidence intervals of population parameters for the purpose of testing significance of assumptions on which statistical inference will be grounded. In section four, multivariate analysis of data variables will be performed to explore differences and associations by use of both parametric and nonparametric techniques. The last section addresses the research findings through studying the results in order to reasoning the phenomenon under study, and extracts some areas for consideration on which the postulate management framework of interest for technological development would be based.

6.2 ASSESSMENT OF INTERNAL CONSISTENCY RELIABILITY

6.2.1 Data Constructs of National Petroleum Research Institute

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
I.2.3	Experimental Development	8	0.930	Excellent
I.2.5	R&D Dependency	10	0.930	Excellent
I.2.8	Structure of R&D Facilities	20	0.906	Excellent

I.2.10	Competency for Technological Assimilation	24	0.723	Acceptable
I.2.11	Inward Technology Transfer	8	0.941	Excellent
I.2.13	Characteristics of Training and Development	25	0.995	Excellent
I.3.2	Barriers to Successful R&D	17	0.865	Good
I.3.3	Barriers to Technology Development	11	0.974	Excellent
I.3.4	Role of Government towards Technology Development	15	0.986	Excellent
I.3.5	Interaction with Oil Companies	29	0.787	Acceptable
I.3.6	Interaction with Universities	34	0.751	Acceptable
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.1): Internal Consistency of Data Constructs of LPI

6.2.2 Data Constructs of National Oil Companies

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
II.2.3	Experimental Development	8	0.958	Excellent
II.2.5	R&D Dependency	10	0.989	Excellent
II.2.6	Generating R&D Ideas	5	0.958	Excellent

II.2.7	Modelling Technology Development	4	0.918	Excellent
II.2.8	Structure of R&D Facilities	20	0.736	Acceptable
II.2.9	Scientific and Technical Output	14	0.881	Good
II.2.10	Competency for Technological Assimilation	28	0.859	Good
II.2.11	Inward Technology Transfer	8	0.749	Acceptable
II.2.12	Dependency on Foreign Supplier	7	0.782	Acceptable
II.2.13	Characteristics of Training and Development	24	0.858	Good
II.3.1	Significance of Petroleum Technology Development	4	0.896	Good
II.3.2	Barriers to Successful R&D	17	0.939	Excellent
II.3.3	Barriers to Technology Development	11	0.939	Excellent
II.3.4	Role of Government towards Technology Development	14	0.944	Excellent
II.3.5	Interaction with Petroleum Research Institute	27	0.904	Excellent

II.3.6	Interaction with Universities	36	0.957	Excellent
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.2): Internal Consistency of Data Constructs of National Oil Companies

6.2.3 Data Constructs of Research Community

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
III.2.1	Job satisfaction	9	0.953	Excellent
III.2.2	Interpersonal Relationships	5	0.851	Good
III.2.3	Information and Communication Process	4	0.856	Good
III.2.4	Organization Culture	6	0.901	Excellent
III.2.5	Learning Climate	5	0.950	Excellent
III.3.1	Absorptive Capacity	4	0.915	Excellent
III.3.2	Conceptualization Capability	5	0.992	Excellent
III.4.1	Barriers to Successful R&D	17	0.979	Excellent
III.4.2	Barriers to Technology Development	11	0.988	Excellent
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.3): Internal Consistency of Data Constructs of Research Community

6.2.4 Data Constructs of Foreign Oil Companies

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
IV.2.3	Barriers to FDI for Technology Development	15	0.943	Excellent
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.4): Internal Consistency of Data Constructs of Foreign Oil Companies

6.2.5 Data Constructs of Public Universities & Research Institutes

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
V.2.3	Experimental Development	8	0.810	Good
V.3.1	Barriers to Successful R&D	15	0.758	Acceptable
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.5): Internal Consistency of Data Constructs of Public Universities & Research Institutes

6.2.6 Data Constructs of Private Companies of Technical Oil Services

NO.	CONSTRUCT	SUBVARIABLES	CRONBACH'S α	I.C.RELIABILTY
VI.2.1	Work Dependency	3	0.905	Excellent
VI.2.4	Supporting Research Activities	8	0.993	Excellent
VI.2.5	Barriers to Supporting Technology Development	12	0.938	Excellent
As a rule of thumb, Chronbach's α > 0.9 (Excellent), > 0.8 (Good), > 0.7 (Acceptable), > 0.6 (Questionable), > 0.5 (Poor), < 0.5 (Unacceptable) (George and Mallery, 2003).				

Table (6.6): Internal Consistency of Data Constructs of Private Companies of Tech. Services

6.3 UNIVARIATE ANALYSIS OF VARIABLES

6.3.1 Technological Competence of National Petroleum Research Institute

Section One: The Organization Profile

NO.	ITEM	DESCRIPTION
I.1.1	Target Population	One national petroleum research institute (Libyan Petroleum Institute)
I.1.2	Percentage of Response	100%
I.1.3	Business-Related Field	Petroleum upstream industry and petroleum downstream industry
I.1.4	Organization Size	300-499 employees
I.1.5	Organization Age	32 years
I.1.6	Organization Ownership	Public ownership
I.1.7	Source of Fund	Public fund and organization's income fund
I.1.8	Respondent Profile	– Institute's general manager – Administrative and training manager – Finance manager

Table (6.7): Organization Profile of LPI

Section Two: Characteristics of Technological Capabilities

– *Involvement in Research and Development*

NO.	VARIABLE	Available	%	To be Available	%	None
I.2.1	Basic Research	0	0	1	100	0
I.2.2	Applied Research	1	100	0	0	0
I.2.3 I.2.3.1–I.2.3.8	Experimental Development – Eight Sub-variables (See Appendix A)	1	12.5	7	87.5	0

Concluding Remarks:

- Libyan petroleum institute is involved in applied research activities.
- Libyan petroleum institute will involve in basic research activities in the future.

- Only 12.5% of experimental development activities are carried out at Libyan petroleum institute.

Table (6.8): Involvement of LPI in Research and Development

– *Research and Development Priorities*

NO.	VARIABLE		
I.2.4	R&D Priorities	Rank	Score
I.2.4.1	– Increasing Stock of Knowledge	1	1.00
I.2.4.2	– Targeting Strategic Technological Opportunities	2	0.923
I.2.4.3	– Meeting Globalization Challenges	3	0.846
I.2.4.4	– Building Technological Self-reliance	4	0.769
I.2.4.5	– Problem Solving for Technical Operations	5	0.692
I.2.4.6	– Enhancing Productivity of Technical Operations	6	0.615
I.2.4.7	– Meeting Technical Demand	7	0.538
I.2.4.8	– Developing International Outlook	8	0.461
I.2.4.9	– Competition Purpose	9	0.385
I.2.4.10	– Reduction of Production Cost	10	0.308
I.2.4.11	– Introducing Novel or Improved Product	11	0.231
I.2.4.12	– Introducing Novel or Improved Process	12	0.154
I.2.4.13	– Waste Reduction	13	0.077

Concluding Remarks:

- Increasing of stock knowledge, targeting strategic technological opportunities, and meeting globalization challenges are respectively the utmost priorities of R&D at Libyan petroleum institute.
- Enhancing productivity of technical operations, meeting technical demand, and developing international outlook have respectively the middle attention of R&D at Libyan petroleum institute.
- Introducing novel or improved product, introducing novel or improved process, and reduction of production waste have respectively the least attention of R&D at Libyan petroleum institute.

Table (6.9): R&D Priorities at LPI

– *Research and Development Dependency*

NO.	VARIABLE	IMPLEMENTATION MODE							
I.2.5	R&D Dependency	I.H	%	N.C.	%	F.C.	%	None	%
I.2.5.1 – I.2.5.10	– Ten Sub-variables (See Appendix A)	3	30	5	50	2	20	0	0

Concluding Remarks:

- 30% of R&D activities at Libyan petroleum institute are executed by its own technical capabilities.
- 50% of R&D activities at Libyan petroleum institute are executed along with national collaboration.
- 20% of R&D activities at Libyan petroleum institute are executed along with foreign collaboration.

I.H.: In-House *N.C.: National Collaboration* *F.C.: Foreign Collaboration*

Table (6.10): R&D Dependency at LPI

– *Generating Research and Development Ideas*

NO.	VARIABLE	IMPLEMENTATION MODE			
I.2.6	Generating R&D Ideas	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.2.6.1	– Internally, involving top management and all researchers of interest.	1	0	0	0
I.2.6.2	– Locally, involving government initiatives.	0	0	1	0
I.2.6.3	– Locally, involving collaboration of universities, research institutes and consultancies	0	1	0	0
I.2.6.4	– Externally, involving collaboration of universities, research institutes and consultancies.	1	0	0	0
I.2.6.5	– Customer request (e.g., national oil companies, foreign oil companies, government agencies, international market demand, etc.)	0	1	0	0

Concluding Remarks: • Involvement of top management and all researchers of interest with collaboration of other external organizations (i.e., universities, research institutes and consultancies) in generating R&D ideas is regularly occurred in LPI. Involvement of local collaboration and customer request is occasionally performed in generating R&D ideas in LPI, while involvement of government initiatives is rarely considered

Table (6.11): Generating R&D Ideas at LPI

– *Modelling Technology Development*

NO.	VARIABLE	IMPLEMENTATION MODE			
I.2.7	Modelling Technology Development (See Appendix A)	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.2.7.1	– Science -Technology Push	0	1	0	0
I.2.7.2	– Network Model	0	0	0	1
I.2.7.3	– Market Pull	0	0	1	0
I.2.7.4	– Interactive Model	1	0	0	0
Concluding Remarks: • The interactive model that combines both the science -technology push and market pull is the regular pattern used in technology development endeavours at Libyan petroleum institute. • The network model of technology development is out of consideration of Libyan petroleum institute.					

Table (6.12): Modelling of Technological Development at LPI

– *Structure of R&D Facilities*

NO.	VARIABLE	AVAILABILITY			
I.2.8A	Physical Facilities	Yes	%	No	%
I.2.8.1– I.2.8.8	– Eight Sub-variables (See Appendix A)	8	100	0	0
NO.	**VARIABLE**	**AVAILABILITY**			
I.2.8B	Intellectual Facilities	Yes	%	No	%

I.2.8.9– I.2.8.20	– Twelve Sub-variables (See Appendix A)	8	66.7	4	33.3

Concluding Remarks:

- 100% of physical R&D facilities are available at Libyan petroleum institute.
- 66.7% of intellectual R&D facilities are available at Libyan petroleum institute.

Table (6.13): Structure of R&D facilities at LPI

– *Scientific and Technical Output*

NO.	VARIABLE	OUTPUT MODE			
I.2.9	Scientific and Technical Output	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.2.9.1	– Research papers	1	0	0	0
I.2.9.2	– Scientific articles	0	1	0	0
I.2.9.3	– Technical bulletins	0	0	1	0
I.2.9.4	– Technical standards	0	0	0	1
I.2.9.5	– Technical directives	0	0	0	1
I.2.9.6	– Technical consultation (i.e., studies)	1	0	0	0
I.2.9.7	– Technical performance reports	1	0	0	0
I.2.9.8	– Scientific books	0	0	1	0
I.2.9.9	– ePublications[1]	1	0	0	0
I.2.9.10	– Technical know-how *(i.e., licences)*	0	0	0	1
I.2.9.11	– Applied patents *(i.e., under verification)*	0	0	0	1
I.2.9.12	– Granted patents	0	0	1	0
I.2.9.13	– Technical copyrights	0	0	0	1
I.2.9.14	– Industrial designs	0	0	0	1

I.2.9.15	– Trademarks	0	0	0	1
Concluding Remarks: • LPI has regular scientific and technical output in terms of research papers, technical studies, technical performance reports and electronic publications. • LPI produces occasionally scientific articles, rarely technical bulletins, rarely scientific books, and rarely granted patents. • LPI does not have any output regarding technical standards, technical directives, know-how licenses, applied patents, technical copyrights, industrial designs, and trademarks.					

Table (6.14): Scientific and Technical Output at LPI

– *Competency for Technological Assimilation*

NO.	VARIABLE	TECHNOLOGY UTILIZATION MODE							
I.2.10	Competency for Technological Assimilation	I.H.	%	N.C.	%	F.C.	%	None	%
I.2.10.1 – I.2.10.24	– Twenty Four Sub-variables (See Appendix A)	20	83.3	0	0	4	16.7	0	0
Concluding Remarks: • 83.3% of technology utilization at Libyan petroleum institute is done by its own technical staff. • Only 16.7% of technology utilization at Libyan petroleum institute is done by foreign collaboration.									

I.H.: In-House N.C.: National Collaboration F.C.: Foreign Collaboration

Table (6.15): Competency for Technological Assimilation at LPI

– *Inward Technology Transfer*

NO.	VARIABLE	TECHNOLOGY TRANSFER MODE			
I.2.11	Inward Technology Transfer	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.2.11.1– I.2.11.8	– Eight Sub-variables (See Appendix A)	7	0	1	0
Population Parameters					

Mean (μ) = 3.75	Standard Deviation (σ) = 0.71	Median (μ̃) = 4.00
Concluding Remarks: • Technology is almost transferred regularly into Libyan petroleum institute.		

Table (6.16): Inward Technology Transfer into LPI

– *Dependency on Foreign Supplier*

NO.	VARIABLE	DEPENDENCY DEGREE				
I.2.12	Dependency on Foreign Supplier (See Appendix A)	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
I.2.12.1	– Machinery	1	0	0	0	0
I.2.12.2	– Raw Material	1	0	0	0	0
I.2.12.3	– Spare Parts	1	0	0	0	0
I.2.12.4	– Technical Support	0	0	1	0	0
I.2.12.5	– Technical Management	0	0	0	1	0
I.2.12.6	– Technical Consultation	0	0	1	0	0
I.2.12.7	– Training and Development	1	0	0	0	0
Concluding Remarks: • LPI is dependent very high on foreign supplier to acquire machinery, raw material, spare parts and performing training and development programmes. • LPI is dependent to medium extent on foreign supplier to get technical support and technical consultation, while dependent very low with respect to technical management						

Table (6.17): Dependency on Foreign Supplier at LPI

– *Characteristics of Training and Development*

NO.	VARIABLE	IMPLEMENTATION MODE							
I.2.13	Characteristics of Training and Development	I.H.	%	N.C.	%	F.C.	%	None	%

I.2.13.1 – I.2.13.25	– Twenty Five Sub-variables. (See Appendix A)	0	0	3	12.0	25	100	0	0
Concluding Remarks: • 100% of training and development programmes at Libyan petroleum institute are conducted by foreign collaboration. • Only 12.0% of training and development programmes at Libyan petroleum institute are conducted along with national collaboration.									

I.H.: In-House N.C.: National Collaboration F.C.: Foreign Collaboration

Table (6.18): Characteristics of Training and Development at LPI

Section Three: *Issues Critical to Technological Development*

– *Significance of Petroleum Technology Development in Libya*

NO.	VARIABLE	DEGREE OF SIGNIFICANCE			
I.3.1A	Significance of Petroleum Technology Development	Very High (4)	High (3)	Medium (2)	Low (1)
I.3.1.1	– Importance of Technology Development to Survival of LPI (See Appendix A)	0	0	0	1
Concluding Remarks: • Significance of technology development to survival has low consideration at Libyan petroleum institute.					
NO.	**VARIABLE**	**AVAILABILITY**			
I.3.1B	Significance of Petroleum Technology Development (See Appendix A)	Yes	%	No	%
I.3.1.2	– Formulating Strategy of Technology Development	1	100	0	0
I.3.1.3	– Involvement in Petroleum Technology Development	1	100	0	0
I.3.1.4	– Government support to National/sectoral Strategy for Technology Development	0	0	1	100
I.3.1.5	– Receiving Fund for Technology Development	0	0	1	100

Concluding Remarks: • Libyan petroleum institute is used to formulate its own strategy to developing technology. • Libyan petroleum institute is used to get involved in efforts of petroleum technology development. • Libyan petroleum institute has not felt yet any government commitment or support to set a national or sectoral S&T strategy. • Libyan petroleum institute has not received yet any kind of local or international fund (FDI) towards technology development.

Table (6.19): Significance of Developing Petroleum Technology to LPI

– *Barriers to Successful R&D Projects*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
I.3.2	Barriers to Successful R&D Projects	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
I.3.2.1 – I.3.2.17	– Seventeen Sub-variables (See Appendix A)	7	1	9	0	0
Population Parameters						
Mean (μ) = 3.88	Standard Deviation (σ) = 0.99		Median ($\tilde{\mu}$) = 3.00			
Concluding Remarks: • Barriers to successful R&D projects are almost existed to high extent at Libyan petroleum institute.						

Table (6.20): Barriers to Successful R&D Projects at LPI

– *Barriers to Technology Development*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
I.3.3	Barriers to Technology Development	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)
I.3.3.1– I.3.3.11	–Eleven Sub-variables (See Appendix A)	10	1	0	0	0
Population Parameters						

Mean (μ) = 4.91	Median (μ̃) = 5.00	Standard Deviation (σ) = 0.30
Concluding Remarks: • Existence of barriers to developing Libyan petroleum technology has almost strong consensus at Libyan petroleum institute.		

Table (6.21): Barriers to Technology Development at LPI

– *Role of Government towards Technology Development*

NO.	VARIABLE	GOVERNMENT INTERVENTION MODE			
I.3.4	Role of Government towards Technology Development	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.3.4.1– I.3.4.15	– Fifteen Sub-variables (See Appendix A)	0	1	14	0
Population Parameters					
Mean (μ) = 2.07	Standard Deviation (σ) = 0.26	Median (μ̃) = 2.00			
Concluding Remarks: • Government support to developing Libyan petroleum technology is almost rarely watched by Libyan petroleum institute.					

Table (6.22): Role of Government towards Technology Development at LPI

– *The Organization Interaction with Oil Companies*

NO.	VARIABLE	IMPLEMENTATION MODE			
I.3.5A	**Interaction with National Oil Companies**	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.3.5.1– I.3.5.15	– Fifteen Sub-variables (See Appendix A)	4	7	4	0
Population Parameters					
Mean (μ) = 3.00	Median (μ̃) = 3.00	Standard Deviation (σ) = 0.75			
NO.	**VARIABLE**	**IMPLEMENTATION MODE**			
I.3.5B	Interaction with Foreign Oil Companies	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)

I.3.5.16– I.3.5.29	– Fourteen Sub-variables (See Appendix A)	8	4	2	0
Population Parameters					
Mean (μ) = 3.42	Median (μ̃) = 4.00	Standard Deviation (σ) = 0.75			
Concluding Remarks: • LPI interaction with national oil company is conducted occasionally. • LPI interaction with foreign oil company is almost conducted occasionally. • LPI interaction with foreign oil company is better than with national oil companies. • The distribution of data describing the interaction with national oil companies has exactly a symmetric shape since the mean is equal to the median.					

Table (6.23): LPI Interaction with Oil Companies

– *The Organization Interaction with Universities & Research Institutes*

NO.	VARIABLE	IMPLEMENTATION MODE			
I.3.6A	Interaction with National Universities/Research Institutes	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.3.6.1– I.3.6.18	– Eighteen Four Sub-variables (See Appendix A)	5	3	4	6
Population Parameters					
Mean (μ) = 2.39	Median (μ̃) = 2.00	Standard Deviation (σ) = 1.24			
NO.	**VARIABLE**	**IMPLEMENTATION MODE**			
I.3.6B	Interaction with Foreign Universities/Research Institutes	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
I.3.6.19– I.3.6.34	– Sixteen Sub-variables (See Appendix A)	5	4	3	4
Population Parameters					
Mean (μ) = 2.62	Median (μ̃) = 3.00	Standard Deviation (σ) = 1.20			
Concluding Remarks: • LPI interaction with national universities/research institutes is almost conducted rarely. • LPI interaction with foreign universities/research institutes is almost conducted occasionally. • LPI interaction with foreign universities/research institutes is better than with national universities/research institutes.					

Table (6.24): LPI Interaction with Universities & Research Institutes

Section Four: Structure of Employment and Expenditures Distribution

– *Structure of R&D Workforce*

NO.	VARIABLE		% Employees					
I.4.1	R&D Personnel		**2003**	**2004**	**2005**	**2006**	**2007**	Mean
I.4.1.1	Researchers	Native	25.0	25.7	25.0	24.6	24.0	24.9
I.4.1.2		Foreign	0.9	0	0	0	0	0.18
I.4.1.3	Technicians	Native	5.4	5.2	5.8	6.3	6.90	5.9
I.4.1.4		Foreign	0	0	0	0	0	0

Concluding Remarks:

- There is about 4% reduction in percentage of native researchers for 2003-2007.
- There is about 27.8% growth in percentage of native technicians for 2003-2007.

Table (6.25): Structure of R&D Workforce at LPI

– *Structure of Scientific Qualifications*

NO.	VARIABLE	% Employees					
I.4.2	Scientific Degree	**2003**	**2004**	**2005**	**2006**	**2007**	Mean
I.4.2.1	– Intermediate diploma	13.8	13.2	13.0	12.8	12.5	13.1
I.4.2.2	– High diploma	3.7	3.6	3.7	3.7	4.3	3.8
I.4.2.3	– Bachelor degree	40.8	39.2	37.8	37.1	36.3	38.2
I.4.2.4	– Master degree	9.2	13.0	17.8	18.1	18.7	15.4
I.4.2.5	– Doctorate degree	4.6	6.3	6.6	6.5	6.4	6.1

Concluding Remarks:

- There is about 11% reduction in percentage of bachelor degree holders for 2003-2007.
- There is about 103% growth in percentage of master degree holders for 2003-2007.
- There is about 39% growth in percentage of doctorate degree holders for 2003-2007.

Table (6.26): Structure of Scientific Qualifications at LPI

– *Structure of Scientific Specialization*

NO.	VARIABLE	% Employees					
I.4.3	Specialization	**2003**	**2004**	**2005**	**2006**	**2007**	Mean
I.4.3.1	– Geologist, Geophysicist and Geochemist	10.3	9.9	9.6	9.4	10.0	9.8
I.4.3.2	– Petroleum Engineer	10.6	10.2	10.1	10.2	10.0	10.2
I.4.3.3	– Chemical Engineer	6.6	6.3	6.6	6.8	6.6	6.6
I.4.3.4	– Chemist	7.2	6.9	6.6	7.1	6.9	6.9
I.4.3.5	– Metallurgist	1.4	1.9	2.1	2.3	2.3	2
I.4.3.6	– Others*	4.3	4.4	4.5	4.4	4.3	4.4

Concluding Remarks:

- There is about 3% reduction in percentage of geologists, geophysicists and geochemists for 2003-2007.
- There is about 6% reduction in percentage of petroleum engineers for 2003-2007.
- There is neither growth nor reduction in percentage of chemical engineers for 2003-2007.
- There is about 4% reduction in percentage of chemists for 2003-2007.

* *Physicists, biologists, mechanical engineers, and electrical/electronic engineers.*

Table (6.27): Structure of Scientific Specialization at LPI

– *Age-Scientific Degree Distribution*

NO.	VARIABLE	% Employees (2007)				
I.4.4	Scientific Degree	**≤ 24 yrs**	**25 – 34**	**35 – 44**	**45 – 54**	**≥ 55**
I.4.4.1	– Intermediate diploma	8.2	30.6	28.6	30.6	2.0
I.4.4.2	– High diploma	0	29.4	47.1	23.5	0
I.4.4.3	– Bachelor degree	0	22.5	42.9	27.5	7.1
I.4.4.4	– Master degree	0	15.1	56.2	26.0	2.7
I.4.4.5	– Doctorate degree	0	0	16.0	76.0	8.0

Concluding Remarks:

- About 43% of bachelor degree holders are at the age of 35-44 years.

- About 56% of master degree holders are at the age of 35-44 years.
- About 76% of doctorate degree holders are at the age of 45-54 years.

Table (6.28): Age-Scientific Degree Distribution at LPI

– *Gender Distribution of Technical Staff*

NO.	VARIABLE	%Technical Staff					
I.4.5	Gender	**2003**	**2004**	**2005**	**2006**	**2007**	Mean
I.4.4.1	– Male	70.9	71.5	71.8	70.1	70.7	71
I.4.4.2	– Female	29.1	28.5	28.2	29.9	29.3	29

Concluding Remarks:

- There is about o.68% growth in percentage of female technical staff for 2003-2007.

Table (6.29): Gender Distribution of Technical Staff at LPI

– *Expenditures Distribution*

NO.	VARIABLE	% Expenditures					
I.4.6	Expenditure Type	**2003**	**2004**	**2005**	**2006**	**2007**	Mean
I.4.6.1	– Research and Development	30	31	32	34	29	31.2
I.4.6.2	– Material	10	9	9	12	11	10.2
I.4.6.3	– Operations (e.g., laboratory services, etc.)	18	21	20	15	19	18.6
I.4.6.4	– Training & Development	10	13	14	18	20	15
I.4.6.5	– Logistics (e.g., maintenance, catering, etc.)	12	8	8	6	7	8.2
I.4.6.6	– Administration (e.g., salaries, etc.)	20	18	17	15	14	16.8

Concluding Remarks:

- 34% of expenditures at LPI are dedicated to R&D activities for 2006.
- There is about 3.4% reduction in percentage of R&D expenditure for 2003-2007.
- There is 100% growth in percentage of training and development expenditure for 2003-2007.

Table (6.30): Expenditures Distribution at LPI

6.3.2 Technological Competence of National Oil Companies

Section One: The Organization Profile

NO.	ITEM	DESCRIPTION
II.1.1	Target Population	Twelve national companies of producing oil and tech services
II.1.2	Respondents	Seven Companies (58%)

Table (6.31): Target Population and Respondents of National Oil Companies

– *Business Type*

NO.	VARIABLE	Company	%
II.1.3	Business Type		
II.1.3.1	– Petroleum Exploration	5	71.4
II.1.3.2	– Petroleum Production	5	71.4
II.1.3.3	– Oil Refining	2	28.6
II.1.3.4	– Petrochemical Manufacturing	1	14.3
II.1.3.5	– Gas Processing	2	28.6
II.1.3.6	– Chemical Manufacturing	1	14.3

Table (6.32): Business Type of National Oil Companies

– *Company Size*

NO.	VARIABLE	≤ 1000 persons	> 1000 - ≤ 2000	> 2000 - ≤ 3000	> 6000 - ≤ 7000
II.1.4	Company Size				
II.1.4.1	No. of Companies	1	3	2	1
		14.3%	42.8%	28.6%	14.3%

Table (6.33): Company Size of National Oil Companies

– *Company Age*

NO.	VARIABLE	> 5 to ≤ 15 yrs	> 15 to ≤ 25 yrs	> 25 to ≤ 35 yrs	> 35 yrs
II.1.5	Company Age				
II.1.5.1	No. of Companies	2	2	2	1
		28.6%	28.6%	28.6%	14.3%

Table (6.34): Company Age of National Oil Companies

– *Company Ownership*

NO.	VARIABLE	Company	%
II.1.6	Company Ownership		
II.1.6.1	– Public Ownership	3	42.8
II.1.6.2	– Shared Ownership	4	57.1

Table (6.35): Company Ownership of National Oil Companies

– *Source of Fund*

NO.	VARIABLE	Company	%
II.1.7	Source of Fund		
II.1.7.1	– Public Fund	7	100
II.1.7.2	– Company's Income Fund	7	100
II.1.7.3	– International Fund	4	57.1

Table (6.36): Source of Fund of National Oil Companies

– *Respondent Profile*

NO.	VARIABLE	Company	%
II.1.8	Respondent Profile		
II.1.8.1	– Member of Executive Board	3	42.8
II.1.8.2	– Planning Manager	2	28.6

II.1.8.3	– Engineering Manager	2	28.6
II.1.8.4	– Operations Manager	3	42.8
II.1.8.5	– Material Manager	4	57.1
II.1.8.6	– Finance Manager	1	14.3
II.1.8.7	– Administrative Manager	2	28.6
II.1.8.8	– Training Manager	7	100
II.1.8.9	– Maintenance Manager	1	14.3
II.1.8.10	– Exploration Manager	2	28.6
II.1.8.11	– Research and Development Manager	1	14.3
II.1.8.12	– Senior Engineering Advisor	1	14.3

Table (6.37): Respondent Profile of National Oil Companies

Section Two: Characteristics of Technological Capabilities

– *Involvement in Research and Development*

<table>
<tr><th>NO.</th><th>VARIABLE</th><th>Available</th><th>%</th><th>To be Available</th><th>%</th><th>None</th><th>%</th></tr>
<tr><td>II.2.1</td><td>Basic Research</td><td>2</td><td>28.6</td><td>0</td><td>0</td><td rowspan="2">3</td><td rowspan="2">42.8</td></tr>
<tr><td>II.2.2</td><td>Applied Research</td><td>3</td><td>42.8</td><td>0</td><td>0</td></tr>
<tr><td>II.2.3
II.2.3.1–II.2.3.8</td><td>Experimental Development
– Eight Sub-variables (See Appendix A)</td><td>5</td><td>8.9</td><td>10</td><td>17.8</td><td>41</td><td>73.3</td></tr>
<tr><td colspan="8">Sample Statistics</td></tr>
<tr><td colspan="2">Basic Research
– Available</td><td colspan="2">Proportion ($\hat{p}$) = 0.286</td><td colspan="4">– Confidence Interval at 95% : (0.060, 0.511)
– Test of Significance: H_o: $p \geq 0.592$, H_a: $p < 0.592$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).</td></tr>
</table>

Applied Research – Available	Proportion ($\hat{p}$) = 0.428	– Confidence Interval at 95% : (0.181, 0.675) – Test of Significance: H_o: $p \geq 0.711$, H_a: $p < 0.711$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
– None	Proportion ($\hat{p}$) = 0.428	– Confidence Interval at 95% : (0.181, 0.675) – Test of Significance: H_o: $p \geq 0.711$, H_a: $p < 0.711$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
Experimental Development – Available	Proportion ($\hat{p}$) = 0.089	– Confidence Interval at 95% : (0.041, 0.137) – Test of Significance: H_o: $p \geq 0.173$, H_a: $p < 0.173$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
– To be Available	Proportion ($\hat{p}$) = 0.178	– Confidence Interval at 95% : (0.113, 0.243) – Test of Significance: H_o: $p \geq 0.277$, H_a: $p < 0.277$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
– None	Proportion ($\hat{p}$) = 0.733	– Confidence Interval at 95% : (0.658, 0.808) – Test of Significance: H_o: $p \geq 0.818$, H_a: $p < 0.818$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).

Concluding Remarks:

- 28.6% of the respondent sample of national oil companies is involved in basic research activities, and probably at less than 59.2% with respect to the population.
- 42.8% of the respondent sample of national oil companies is involved in applied research activities, and probably at less than 71.1% with respect to the population.
- 8.9% of experimental development activities are carried out by the respondent sample of national oil companies, and probably at less than 17.3% with respect to the population.
- 17.8% of experimental development activities will be done by the respondent sample of national oil companies, and probably at less than 27.7% with respect to the population.
- 73.3% of experimental development activities neither carried out nor will be carried out by the respondent sample of national oil companies, and probably at less than 81.8% with respect to the population.

Table (6.38): Involvement of National Oil Companies in Research and Development

– *Research and Development Priorities*

NO.	VARIABLE		
II.2.4	R&D Priorities	Rank	Score
II.2.4.1	– Reduction of Production Cost	1	1.00
II.2.4.2	– Problem Solving for Technical Operations	2	0.923
II.2.4.3	– Enhancing Productivity of Technical Operations	3	0.846
II.2.4.4	– Waste Reduction	4	0.769
II.2.4.5	– Introducing Novel or Improved Process	5	0.692
II.2.4.6	– Meeting Technological Demand	6	0.615
II.2.4.7	– Building Technological Self-reliance	7	0.538
II.2.4.8	– Introducing Novel or Improved Product	7	0.538
II.2.4.9	– Competition Purpose	9	0.385
II.2.4.10	– Increasing stock of knowledge	10	0.308
II.2.4.11	– Meeting Globalization Challenges	11	0.231
II.2.4.12	– Developing International Outlook	12	0.154
II.2.4.13	– Targeting Strategic Technological Opportunities	13	0.077

Concluding Remarks:

- Reduction of production cost, problem solving for technical operations, and enhancing productivity of technical operations are respectively the utmost priorities of R&D at the respondent sample of national oil companies.
- Introducing novel or improved process, building technological self-reliance, and introducing novel or improved product have respectively the middle attention of R&D at the respondent sample of national oil companies.
- Meeting globalization challenges, developing international outlook, targeting strategic technological opportunities have respectively the least attention of R&D at the respondent sample of national oil companies.

Table (6.39): R&D Priorities of National Oil Companies

– *Research and Development Dependency*

NO.	VARIABLE	IMPLEMENTATION MODE							
II.2.5	R&D Dependency	I.H.	%	N.C.	%	F.C.	%	None	%
II.2.5.1– II.2.5.10	– Ten Sub-variables (See Appendix A)	30	42.8	5	7.1	7	10	40	57.1

Sample Proportions		
– I.H.	Proportion ($\hat{p}$) = 0.428	– Confidence Interval at 95% : (0.353, 0.503) – Test of Significance: H_o: $p \geq 0.527$, H_a: $p < 0.527$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
– N.C.	Proportion ($\hat{p}$) = 0.071	– Confidence Interval at 95% : (0.032, 0.109) – Test of Significance: H_o: $p \geq 0.140$, H_a: $p < 0.140$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
– F.C	Proportion ($\hat{p}$) = 0.100	– Confidence Interval at 95% : (0.054, 0.145) – Test of Significance: H_o: $p \geq 0.175$, H_a: $p < 0.175$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.571	– Confidence Interval at 95% : (0.496, 0.646) – Test of Significance: H_o: $p \geq 0.664$, H_a: $p < 0.664$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
Concluding Remarks: • 42.8% of the respondent sample of national oil companies is dependent on their own technical capabilities to perform R&D cornerstones, and probably at less than 52.7% with respect to the population. • Only 7.1% of the respondent sample of national oil companies is dependent on national collaboration to perform R&D cornerstones, and probably at less than 14% with respect to the population. • Only 10% of the respondent sample of national oil companies is dependent on foreign collaboration to perform R&D cornerstones, and probably at less than 17.5% with respect to the population. • 57.1% of the respondent sample of national oil companies has not performed R&D cornerstones, and probably at less than 66.4% with respect to the population.		

I.H.: In-House *N.C.: National Collaboration* *F.C.: Foreign Collaboration*

Table (6.40): R&D Dependency at National Oil Companies

– *Generating Research and Development Ideas*

NO.	VARIABLE	IMPLEMENTATION MODE			
II.2.6	Generating R&D Ideas	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)

II.2.6.1– I.2.6.5	– Five Sub-variables (See Appendix A)	5	3	4	23
Sample Statistics					
Mean ($\bar{x}$) = 1.71	Confidence Interval at 95% : (1.33, 2.10)	Median ($\tilde{x}$) = 1.00	Standard Deviation (s) = 1.13		
Test of Significance: H_o: $\mu \geq 2.034$, H_a: $\mu < 2.034$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446).					
Concluding Remarks: • Generating of R&D ideas is almost rarely performed at both the respondent sample and the population of national oil companies.					

Table (6.41): Generating R&D Ideas at National Oil Companies

– *Modelling Technological Development*

NO.	VARIABLE	IMPLEMENTATION MODE			
II.2.7	Modelling Technology Development	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.2.7.1– II.2.7.4	– Four Sub-variables (See Appendix A)	5	2	4	17
Sample Statistics					
Mean ($\bar{x}$) = 1.82	Confidence Interval at 95% : (1.36, 2.28)	Median ($\tilde{x}$) = 1.00	Standard Deviation (s) = 1.19		
Test of Significance: H_o: $\mu \geq 2.204$, H_a: $\mu < 2.204$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0436).					
Concluding Remarks: • Modelling technology development is almost rarely performed at both the respondent sample and the population of national oil companies.					

Table (6.42): Modelling of Technological Development at National Oil Companies

– *Structure of R&D Facilities*

NO.	VARIABLE	AVAILABILITY			
II.2.8A	Physical Facilities	Yes	%	No	%
II.2.8.1– II.2.8.8	– Eight Sub-variables (See Appendix A)	24	42.9	32	57.1

NO.	VARIABLE	AVAILABILITY			
II.2.8B	Intellectual Facilities	Yes	%	No	%
II.2.8.9– II.2.8.20	– Twelve Sub-variables (See Appendix A)	30	35.7	54	64.3

Sample Proportions

Physical Facilities – Available	Proportion ($\hat{p}$) = 0.429	– Confidence Interval at 95% : (0.345, 0.513) – Test of Significance: H_o: $p \geq 0.539$, H_a: $p < 0.539$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– Not Available	Proportion ($\hat{p}$) = 0.571	– Confidence Interval at 95% : (0.487, 0.655) – Test of Significance: H_o: $p \geq 0.675$, H_a: $p < 0.675$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Intellectual Facilities – Available	Proportion ($\hat{p}$) = 0.357	– Confidence Interval at 95% : (0.291, 0.423) – Test of Significance: H_o: $p \geq 0.447$, H_a: $p < 0.447$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
– Not Available	Proportion ($\hat{p}$) = 0.643	– Confidence Interval at 95% : (0.577, 0.709) – Test of Significance: H_o: $p \geq 0.724$, H_a: $p < 0.724$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).

Concluding Remarks:

- The respondent sample of national oil companies has possessed 42.9% of physical R&D facilities, and probably at less than 53.9% with respect to the population.
- The respondent sample of national oil companies has not possessed 57.1% of physical R&D facilities, and probably at less than 67.5% with respect to the population.
- The respondent sample of national oil companies has possessed 35.7% of intellectual R&D facilities, and probably at less than 44.7% with respect to the population.
- The respondent sample of national oil companies has not possessed 64.3% of intellectual R&D facilities, and probably at less than 72.4% with respect to the population.

Table (6.43): Structure of R&D facilities at National Oil Companies

– *Scientific and Technical Output*

NO.	VARIABLE	OUTPUT MODE			
II.2.9	Scientific and Technical Output	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.2.9.1– II.2.9.14	– Fourteen Sub-variables (See Appendix A)	6	13	28	51
Sample Statistics					
Mean ($\bar{x}$) = 1.73	Confidence Interval at 95% : (1.55, 1.92)	Median ($\tilde{x}$) = 1.00	Standard Deviation (s) = 0.91		
Test of Significance: H_o: $\mu \geq 1.883$, H_a: $\mu < 1.883$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).					
Concluding Remarks: • Scientific and technical output is almost rare at both the respondent sample and the population of national oil companies.					

Table (6.44): Scientific and Technical Output at National Oil Companies

– *Competency for Technological Assimilation*

NO.	VARIABLE	TECHNOLOGY UTILIZATION MODE							
II.2.10	Competency for Technological Assimilation	I.H.	%	N.C.	%	F.C.	%	None	%
II.2.10.1 – II.2.10.28	– Twenty Eight Sub-variables (See Appendix A)	79	40.3	26	13.3	73	37.2	83	42.3
Sample Proportions									
– I.H.	Proportion ($\hat{p}$) = 0.403	– Confidence Interval at 95% : (0.359, 0.447) – Test of Significance: H_o: $p \geq 0.462$, H_a: $p < 0.462$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).							
– N.C.	Proportion ($\hat{p}$) = 0.133	– Confidence Interval at 95% : (0.102, 0.164) – Test of Significance: H_o: $p \geq 0.178$, H_a: $p < 0.178$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).							

– F.C	Proportion ($\hat{p}$) = 0.372	– Confidence Interval at 95% : (0.328, 0.416) – Test of Significance: H_o: $p \geq 0.431$, H_a: $p < 0.431$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).
– None	Proportion ($\hat{p}$) = 0.423	– Confidence Interval at 95% : (0.378, 0.468) – Test of Significance: H_o: $p \geq 0.482$, H_a: $p < 0.482$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Concluding Remarks: • 40.3% of petroleum technologies are operated at the respondent sample of national oil companies by their own technical capabilities, and probably at less than 46.2% with respect to the population. • 13.3% of petroleum technologies are operated at the respondent sample of national oil companies by national collaboration, and probably at less than 17.8% with respect to the population. • 37.2% of petroleum technologies are operated at the respondent sample of national oil companies by foreign collaboration, and probably at less than 43.1% with respect to the population. • 42.3% of petroleum technologies are not utilized at the respondent sample of national oil companies either because of lack of accessibility or irrelevance to work, and probably at less than 48.2% with respect to the population.		

I.H.: In-House *N.C.: National Collaboration* *F.C.: Foreign Collaboration*

Table (6.45): Competency for Technological Assimilation at National Oil Companies

– *Inward Technology Transfer*

NO.	VARIABLE	TECHNOLOGY TRANSFER MODE			
II.2.11	Inward Technology Transfer	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.2.11.1– I.2.11.8	– Eight Sub-variables (See Appendix A)	20	18	15	3
Sample Statistics					
Mean ($\bar{x}$) = 2.98	Confidence Interval at 95% : (2.73, 3.23)	Median ($\tilde{x}$) = 3.00	Standard Deviation (s) = 0.92		
Test of Significance: H_o: $\mu \geq 3.184$, H_a: $\mu < 3.184$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0470).					
Concluding Remarks: • Technology transfer into both the respondent sample and the population of national oil					

companies is almost performed occasionally. • The distribution of data tends to have a symmetric shape since the mean is approximately equal to the median.

Table (6.46): Inward Technology Transfer to National Oil Companies

– *Dependency on Foreign Supplier*

NO.	VARIABLE	DEPENDENCY DEGREE				
II.2.12	Dependency on Foreign Supplier	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
II.2.12.1– II.2.12.7	– Seven Sub-variables (See Appendix A)	14	16	13	4	2
Sample Statistics						
Mean ($\bar{x}$) = 3.73	Confidence Interval at 95% : (3.42, 4.05)	Median ($\tilde{x}$) = 4.00		Standard Deviation (s) = 1.09		
Test of Significance: H_o: $\mu \geq 3.992$, H_a: $\mu < 3.992$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446).						
Concluding Remarks: • Dependency on foreign supplier is almost highly considered at both the respondent sample and the population of national oil companies.						

Table (6.47): Dependency on Foreign Supplier at National Oil Companies

– *Characteristics of Training and Development*

NO.	VARIABLE	IMPLEMENTATION MODE							
II.2.13	Characteristics of Training and Development	I.H.	%	N.C.	%	F.C.	%	None	%
II.2.13.1 – II.2.13.24	– Twenty Four Sub-variables (See Appendix A)	34	20.2	38	22.6	83	49.4	51	30.3
Sample Proportions									
– I.H.	Proportion ($\hat{p}$) = 0.202	– Confidence Interval at 95% : (0.163, 0.241) – Test of Significance: H_o: $p \geq 0.258$, H_a: $p < 0.258$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).							

– N.C.	Proportion ($\hat{p}$) = 0.226	– Confidence Interval at 95% : (0.185, 0.267) – Test of Significance: H_o: $p \geq 0.284$, H_a: $p < 0.284$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480
– F.C	Proportion ($\hat{p}$) = 0.494	– Confidence Interval at 95% : (0.445, 0.543) – Test of Significance: H_o: $p \geq 0.558$, H_a: $p < 0.558$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).
– None	Proportion ($\hat{p}$) = 0.303	– Confidence Interval at 95% : (0.258, 0.348) – Test of Significance: H_o: $p \geq 0.365$, H_a: $p < 0.365$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).
Concluding Remarks: • 20.2% of training and development programmes are conducted by in-house capabilities at the respondent sample of national oil companies, and probably at less than 25.8% with respect to the population. • 22.6% of training and development programmes are conducted by national collaboration at the respondent sample of national oil companies, and probably at less than 28.4% with respect to the population. • 49.4% of training and development programmes are conducted by foreign collaboration at the respondent sample of national oil companies, and probably at less than 55.8% with respect to the population. • 30.3% of training and development programmes are not conducted at the respondent sample of national oil companies, and probably at less than 36.5% with respect to the population.		

I.H.: In-House N.C.: National Collaboration F.C.: Foreign Collaboration

Table (6.48): Characteristics of Training and Development at National Oil Companies

Section Three: Issues Critical to Technological Development

– *Significance of Petroleum Technology Development in Libya*

NO.	VARIABLE	DEGREE OF SIGNIFICANCE			
II.3.1A	Significance of Petroleum Technology Development	Very High (4)	High (3)	Medium (2)	Low (1)
II.3.1.1	– Importance of Technology Development to Survival of LPI (See Appendix A)	0	3	1	3

Sample Statistics			
Mean ($\bar{x}$) = 2.00	Confidence Interval at 95% : (1.07, 2.92)	Median ($\tilde{x}$) = 2.00	Standard Deviation (s) = 1.00
Test of Significance: H_o: $\mu \geq 2.735$, H_a: $\mu < 2.735$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0259).			
Concluding Remarks: • Significance of technology development to survival has a medium-level of consideration at both the respondent sample and the population of national oil companies.			

NO.	VARIABLE	AVAILABILITY			
II.3.1B	Significance of Petroleum Technology Development	Yes	%	No	%
II.3.1.2	– Formulating Strategy of Technology Development (See Appendix A)	3	42.8	4	57.2
II.3.1.3	– Involvement in Petroleum Technology Development (See Appendix A)	2	28.6	5	71.4
II.3.1.4	– Government support to National/sectoral Strategy for Technology Development (See Appendix A)	0	0	7	100
II.3.1.5	– Receiving Fund for Technology Development (See Appendix A)	1	14.3	6	85.7

Sample Statistics		
Formulating Technology Strategy – *Available*	Proportion ($\hat{p}$) = 0.428	– Confidence Interval at 95% : (0.181, 0.675) – Test of Significance: H_o: $p \geq 0.711$, H_a: $p < 0.711$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– *Not Available*	Proportion ($\hat{p}$) = 0.572	– Confidence Interval at 95% : (0325., 0.819) – Test of Significance: H_o: $p \geq 0.815$, H_a: $p < 0.815$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
Involvement in Technology Development – *Available*	Proportion ($\hat{p}$) = 0.286	– Confidence Interval at 95% : (0.060, 0.512) – Test of Significance: H_o: $p \geq 0.592$, H_a: $p <$

– *Not Available*	Proportion ($\hat{p}$) = 0.714	0.592. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495). – Confidence Interval at 95% : (0.488, 0.940) – Test of Significance: H_o: $p \geq 0.901$, H_a: $p < 0.901$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
Receiving Fund – *Available*	Proportion ($\hat{p}$) = 0.143	– Confidence Interval at 95% : (0.000, 0.318) – Test of Significance: H_o: $p \geq 0.453$, H_a: $p < 0.453$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– *Not Available*	Proportion ($\hat{p}$) = 0.857	– Confidence Interval at 95% : (0.682, 1.000) – Test of Significance: H_o: $p \geq 0.968$, H_a: $p < 0.968$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).

Concluding Remarks:

- 42.8% of the respondent sample of national oil companies is used to formulate their own strategy of petroleum technology development, and probably at less than 71.1% with respect to the population.
- 57.2% of the respondent sample of national oil companies is not used to formulate their own strategy of petroleum technology development, and probably at less than 81.5% with respect to the population.
- 28.6% of the respondent sample of national oil companies is involved in efforts of petroleum technology development, and probably at less than 59.2% with respect to the population.
- 71.4% of the respondent sample of national oil companies is not involved in efforts of petroleum technology development, and probably at less than 90.1% with respect to the population.
- 100% of the respondent sample of national oil companies has not felt any government support to set a national/sectoral S&T strategy.
- 14.3% of the respondent sample of national oil companies has received some kind of fund for petroleum technology development, and probably at less than 45.3% with respect to the population.
- 85.7% of the respondent sample of national oil companies has not received any kind of fund for petroleum technology development, and probably at less than 96.8% with respect to the population.

Table (6.49): Significance of Petroleum Technology Development to National Oil Companies

– *Barriers to Successful R&D Projects*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
II.3.2	Barriers to Successful R&D Projects	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
II.3.2.1– II.3.2.17	– Seventeen Sub-variables (See Appendix A)	37	46	24	11	1
Sample Statistics						
Mean ($\bar{x}$) = 3.90	Confidence Interval at 95% : (3.72, 4.08)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 0.98			
Test of Significance: H_o: $\mu \geq 4.05$, H_a: $\mu < 4.05$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).						
Concluding Remarks: • Barriers to successful R&D projects are almost existed to high extent at both the respondent sample and the population of national oil companies.						

Table (6.50): Barriers to Successful R&D Projects at National Oil Companies

– *Barriers to Technology Development*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
II.3.3	Barriers to Technology Development	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)
II.3.3.1– II.3.3.11	– Eleven Sub-variables (See Appendix A)	16	46	11	4	0
Sample Statistics						
Mean ($\bar{x}$) = 3.96	Confidence Interval at 95% : (3.79, 4.13)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 0.75			
Test of Significance: H_o: $\mu \geq 4.103$, H_a: $\mu < 4.103$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0470).						
Concluding Remarks: • Existence of barriers to developing Libyan petroleum technology has clear consensus of both the						

respondent sample and the population of national oil companies.
• The distribution of data tends to have a symmetric shape since the mean is approximately equal to the median.

Table (6.51): Barriers to Technology Development at National Oil Companies

– *Role of Government towards Technology Development*

NO.	VARIABLE	GOVERNMENT INTERVENTION MODE			
II.3.4	Role of Government towards Technology Development	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.3.4.1–II.3.4.14	– Fourteen Sub-variables (See Appendix A)	3	23	54	18
Sample Statistics					
Mean ($\bar{x}$) = 2.11	Confidence Interval at 95% : (1.96, 2.26)	Median ($\tilde{x}$) = 2.00	Standard Deviation (s) = 0.73		
Test of Significance: H_o: $\mu \geq 2.233$, H_a: $\mu < 2.233$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).					
Concluding Remarks: • Government support to developing Libyan petroleum technology is almost rarely observed by both the respondent sample and the population of national oil companies.					

Table (6.52): Role of Government towards Technology Development at National Oil Companies

– *The Companies Interaction with Petroleum Research Institutes*

NO.	VARIABLE	IMPLEMENTATION MODE			
II.3.5A	Interaction with LPI	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.3.5.1–II.3.5.15	– Fifteen Sub-variables (See Appendix A)	10	28	38	29
Sample Statistics					
Mean ($\bar{x}$) = 2.09	Confidence Interval at 95% : (1.90, 2.29)	Median ($\tilde{x}$) = 2.00	Standard Deviation (s) = 1.00		
Test of Significance: H_o: $\mu \geq 2.253$, H_a: $\mu < 2.253$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).					

NO.	VARIABLE	IMPLEMENTATION MODE			
II.3.5B	Interaction with Foreign Petroleum Research Institutes	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.3.5.16– II.3.5.27	– Twelve Sub-variables (See Appendix A)	4	19	30	31
Sample Statistics					
Mean ($\bar{x}$) = 1.95	Confidence Interval at 95% : (1.76, 2.14)	Median ($\tilde{x}$) = 2.00	Standard Deviation (s) = 0.89		
Test of Significance: H_o: $\mu \geq 2.112$, H_a: $\mu < 2.112$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).					
Concluding Remarks: • Interactions of both the respondent sample and the population of national oil companies with LPI are almost conducted rarely. • Interactions of both the respondent sample and the population of national oil companies with foreign petroleum research institutes are almost conducted rarely. • Interaction with LPI is better than with foreign petroleum research institutes.					

Table (6.53): Interaction of National Oil Companies with Petroleum Research Institutes

– *The Companies Interaction with Universities & Research Institutes*

NO.	VARIABLE	IMPLEMENTATION MODE			
II.3.6A	Interaction with National Universities/Research Institutes	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
II.3.6.1– II.3.6.18	– Eighteen Sub-variables (See Appendix A)	4	30	48	44
Sample Statistics					
Mean ($\bar{x}$) = 1.95	Confidence Interval at 95% : (1.80, 2.10)	Median ($\tilde{x}$) = 2.00	Standard Deviation (s) = 0.85		
Test of Significance: H_o: $\mu \geq 2.076$, H_a: $\mu < 2.076$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).					
NO.	**VARIABLE**	**IMPLEMENTATION MODE**			
II.3.6B	Interaction with Foreign Universities/Research Institutes	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)

II.3.6.19 – II.3.6.36	– Eighteen Sub-variables (See Appendix A)	6	16	37	67

Sample Statistics			
Mean ($\bar{x}$) = 1.69	Confidence Interval at 95% : (1.54, 1.84)	Median ($\tilde{x}$) = 1.00	Standard Deviation (s) = 0.87

Test of Significance: H_o: $\mu \geq 1.819$, H_a: $\mu < 1.819$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).

Concluding Remarks:

- Interactions of both the respondent sample and the population of national oil companies with national universities/research institutes are almost conducted rarely.
- Interactions of both the respondent sample and the population of national oil companies with foreign universities/research institutes are almost conducted rarely.
- Interaction with national universities/research institutes is better than with foreign universities/research institutes.

Table (6.54): Interaction of National Oil Companies with Universities & Research Institutes

6.3.3 Technological Competency of Research Community

Section One: The Respondent Profile

NO.	ITEM	DESCRIPTION
III.1.1	Target Population	103 persons (Full time: 94; Part time: 9)
III.1.2	Respondents	72 persons (Full time: 68; Part time: 4), 70%

Table (6.55): Target Population and Research Personnel Respondents

– *Respondent Profession*

NO.	VARIABLE	Full Time	Part Time	Total	%
III.1.3	Respondent Profession				
III.1.3.1	– Senior Researcher	7	2	9	12.5
III.1.3.2	– Researcher	2	1	3	4.2
III.1.3.3	– Senior Assistance Researcher	41	1	42	58.3
III.1.3.4	– Assistance Researcher	18	0	18	25.0
	Gross Total	**68**	**4**	**72**	**100**

Table (6.56): Respondent Profession of Research Personnel

– *Respondent Experience*

NO.	VARIABLE	Full Time	Part Time	Total	%
III.1.4	Duration				
III.1.4.1	> 20 years	28	3	31	43.0
III.1.4.2	16 – 20 years	13	0	13	18.0
III.1.4.3	11 – 15 years	12	0	12	16.7
III.1.4.4	5 – 10 years	13	1	14	19.5
III.1.4.5	< 5 years	2	0	2	2.8
	Gross Total	**68**	**4**	**72**	**100**

Table (6.57): Respondent Experience of Research Personnel

– *Respondent Scientific Qualification*

NO.	VARIABLE	Full Time	Part Time	Total	%
III.1.5	Scientific Degree				
III.1.5.1	– PhD	9	3	12	16.7
III.1.5.2	– MPhill	3	0	3	4.2
III.1.5.3	– MSc	40	0	40	55.5
III.1.5.4	– BSc	16	1	17	23.6
	Gross Total	**68**	**4**	**72**	**100**

Table (6.58): Respondent Scientific Qualification

– *Respondent Place of Work*

NO.	VARIABLE	Petroleum Research Institute	University	Other Research Institute	Oil Company
III.1.6	Place of Work				
III.1.6.1	Number of Respondent	68	3	1	0
III.1.6.2	%	94.4	4.2	1.4	00.0

Table (6.59): Respondent Place of Work within Research Community

Section Two: Characteristics of Work Environment

– *Job Satisfaction*

NO.	VARIABLE	SCALE				
III.2.1	Job Satisfaction	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
III.2.1.1– III.2.1.9	− Nine Sub-variables (See Appendix A)	28	118	97	321	84

Sample Statistics			
Mean ($\bar{x}$) = 3.49	Confidence Interval at 95% : (3.40, 3.57)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 1.06

Test of Significance: H_o: $\mu \geq 3.56$, H_a: $\mu < 3.56$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0465).

Concluding Remarks:

- The respondent sample and the population of research personnel are almost neither disagree nor agree about their job satisfaction.

Table (6.60): Job Satisfaction of Research Personnel

– *Interpersonal Relationships*

NO.	VARIABLE	SCALE				
III.2.2	Interpersonal Relationships	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
III.2.2.1– III.2.2.5	− Five Sub-variables (See Appendix A)	15	93	52	144	56

Sample Statistics			
Mean ($\bar{x}$) = 3.37	Confidence Interval at 95% : (3.25, 3.49)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 1.15

Test of Significance: H_o: $\mu \geq 3.47$, H_a: $\mu < 3.47$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).

Concluding Remarks:

- The respondent sample and the population of research personnel are almost neither disagree nor agree about the effectiveness of their interpersonal relationships.

Table (6.61): Interpersonal Relationships within Research Community

– *Information and Communication Process*

NO.	VARIABLE	SCALE				
III.2.3	Information and Communication Process	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
III.2.3.1	– Accessibility to Information (See Appendix A)	5	18	6	35	8
III.2.3.2	– Up-to-date Information (See Appendix A)	5	24	13	23	7
III.2.3.3	– Weakness of Information Flow (See Appendix A)	1	8	12	37	14
III.2.3.4	– Share of Information (See Appendix A)	7	33	11	19	2

Sample Statistics

– *Accessibility to Information*

Mean ($\bar{x}$) = 3.32 , Confidence Interval at 95% : (3.04, 3.59), Median ($\tilde{x}$) = 4.00 , Standard Deviation (s) = 1.17

Test of Significance: H_o: $\mu \geq 3.55$, H_a: $\mu < 3.55$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0480).

– *Up-to-date Information*

Mean ($\bar{x}$) = 3.04 , Confidence Interval at 95% : (2.77, 3.31), Median ($\tilde{x}$) = 3.00 , Standard Deviation (s) = 1.15

Test of Significance: H_o: $\mu \geq 3.27$, H_a: $\mu < 3.27$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0450).

– *Weakness of Information flow*

Mean ($\bar{x}$) = 3.76 , Confidence Interval at 95% : (3.54, 3.98), Median ($\tilde{x}$) = 4.00 , Standard Deviation (s) = 0.94

Test of Significance: H_o: $\mu \geq 3.95$, H_a: $\mu < 3.95$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0431).

– *Share of Information*

Mean ($\bar{x}$) = 2.66 , Confidence Interval at 95% : (2.42, 2.92), Median ($\tilde{x}$) = 2.00 , Standard Deviation (s) = 1.06

Test of Significance: H_o: $\mu \geq 2.87$, H_a: $\mu < 2.87$

The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0465).

Concluding Remarks:

- The respondent sample and the population of research personnel tend to neither disagree nor agree about their accessibility to relevant information.
- The respondent sample and the population of research personnel are almost neither disagree nor agree about the effectiveness of information updating at their research community.
- The respondent sample and the population of research personnel are almost agree about the weakness of information flow through their research community.
- The respondent sample and the population of research personnel tend to neither disagree nor agree about their share of relevant information.
- The distribution of data describing updating of information tends to have a symmetric shape since the mean is approximately equal to the median.

Table (6.62): Information and Communication Process within Research Community

– *Organization Culture*

NO.	VARIABLE	SCALE				
III.2.4	Organization Culture	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
III.2.4.1	– Organization welfare rather than personal interests. (See Appendix A)	6	23	18	22	3
III.2.4.2	– Loyalty before capability. (See Appendix A)	1	7	21	30	13
III.2.4.3	– Time insignificance. (See Appendix A)	2	5	9	35	21

III.2.4.4	– Surrender to change. (See Appendix A)	8	18	17	28	1
III.2.4.5	– Interest in work. (See Appendix A)	6	23	16	22	5
III.2.4.6	– No real challenging work. (See Appendix A)	1	7	10	40	14
Sample Statistics						
– *Organization Welfare rather than Personal Interests* Mean ($\bar{x}$) = 2.90 , Confidence Interval at 95% : (2.65, 3.15), Median ($\tilde{x}$) = 3.00 , Standard Deviation (s) = 1.06 Test of Significance: H_o: $\mu \geq 3.11$, H_a: $\mu < 3.11$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0465).						
– *Loyalty before Capability* Mean ($\bar{x}$) = 3.65 , Confidence Interval at 95% : (3.43, 3.87), Median ($\tilde{x}$) = 4.00 , Standard Deviation (s) = 0.94 Test of Significance: H_o: $\mu \geq 3.84$, H_a: $\mu < 3.84$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0431).						
– *Time Insignificance* Mean ($\bar{x}$) = 3.94 , Confidence Interval at 95% : (3.71, 4.17), Median ($\tilde{x}$) = 4.00 , Standard Deviation (s) = 0.98 Test of Significance: H_o: $\mu \geq 4.14$, H_a: $\mu < 4.14$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0418).						
– *Surrender to Change* Mean ($\bar{x}$) = 2.94 , Confidence Interval at 95% : (2.69, 3.19), Median ($\tilde{x}$) = 3.00 , Standard Deviation (s) = 1.07 Test of Significance: H_o: $\mu \geq 3.16$, H_a: $\mu < 3.16$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0406).						
– *Interest in Work* Mean ($\bar{x}$) = 2.96 , Confidence Interval at 95% : (2.69, 3.22), Median ($\tilde{x}$) = 3.00 , Standard Deviation (s) = 1.12 Test of Significance: H_o: $\mu \geq 3.19$, H_a: $\mu < 3.19$						

The test results are statistically significant at α = 0.05 (P-value = 0.0407).
– *No Real Challenging Work* Mean ($\bar{x}$) = 3.82 , Confidence Interval at 95% : (3.60, 4.03), Median ($\tilde{x}$) = 4.00 , Standard Deviation (s) = 0.91 Test of Significance: H_o: $\mu \geq 4.00$, H_a: $\mu < 4.00$ The test results are statistically significant at α = 0.05 (P-value = 0.0465).
Concluding Remarks: • The respondent sample and the population of research personnel are almost neither disagree nor agree about enhancing the individuals at Libyan public organizations to the organization welfare rather than personnel interest. • The respondent sample and the population of research personnel tend to agree about the widespread belief among most of Libyan organizations that, loyalty before capability when recruiting or assigning work leaders of all levels. • The respondent sample and the population of research personnel are almost agree that time is not much important in daily work life of Libyans. • The respondent sample and the population of research personnel are almost neither disagree nor agree that resistance to change is not big barrier in most of Libyan organizations. • The respondent sample and the population of research personnel are almost neither disagree nor agree that most of Libyan individuals believe that, work is worthy to pay much attention as there is real rewarding and promotion systems available. • The respondent sample and the population of research personnel are almost agree that in most of Libyan organizations no real challenging works being seriously considered. • The distribution of data describing interest in work tends to have a symmetric shape since the mean is approximately equal to the median.

Table (6.63): Characteristics of Organization Culture

– *Learning Climate*

NO.	VARIABLE	SCALE				
III.2.5	Learning Climate	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
III.2.5.1–III.2.5.5	– Five Sub-variables (See Appendix A)	32	107	151	64	6

Sample Statistics			
Mean ($\bar{x}$) = 2.74	Confidence Interval at 95% : (2.64, 2.83)	Median ($\tilde{x}$) = 3.00	Standard Deviation (s) = 0.91

Test of Significance: H_o: $\mu \geq 2.82$, H_a: $\mu < 2.82$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).
Concluding Remarks: • The learning climate surrounding the respondent sample and the population of research personnel tends to be at moderate effectiveness degree.

Table (6.64): Learning Climate of Research Community

– *Managerial System*

NO.	VARIABLE	SCALE			
III.2.6A	Leader-Member Relationship	Very Poor (1)	Poor (2)	Good (3)	Very Good (4)
III.2.6.1	– One Sub-variable (See Appendix A)	2	20	40	10
III.2.6B	Conflict of Commands	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
III.2.6.2	– One Sub- variable (See Appendix A)	6	23	28	15
III.2.6C	Participation in Decision Making	Most participate (3)	Few participate (2)	None participate (1)	
III.2.6.3	– One Sub- variable (See Appendix A)	5	52	15	
III.2.6D	Recognition of Job Description	Written Manner (3)	Verbal Manner (2)	Self-learning Manner (1)	
III.2.6.4	– One Sub- variable (See Appendix A)	12	11	49	
Sample Statistics					
– *Leader-member Relationship* Mean ($\bar{x}$) = 2.81 , Confidence Interval at 95% : (2.64, 2.97), Median ($\tilde{x}$) = 3.00 , Standard Deviation (s) = 0.70 Test of Significance: H_o: $\mu \geq 2.95$, H_a: $\mu < 2.95$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).					

– *Conflict of Commands* Mean ($\bar{x}$) = 2.28 , Confidence Interval at 95% : (2.07, 2.49), Median ($\tilde{x}$) = 2.00 , Standard Deviation (s) = 0.89 Test of Significance: H_o: μ ≥ 2.46, H_a: μ < 2.46 The test results are statistically significant at α = 0.05 (P-value = 0.0431).
– *Participation in Decision Making* Mean ($\bar{x}$) = 1.86 , Confidence Interval at 95% : (1.74, 1.98), Median ($\tilde{x}$) = 2.00 , Standard Deviation (s) = 0.51 Test of Significance: H_o: μ ≥ 1.97, H_a: μ < 1.97 The test results are statistically significant at α = 0.05 (P-value = 0.0336).
– *Recognition of Job Description* Mean ($\bar{x}$) = 1.49 , Confidence Interval at 95% : (1.30, 1.67), Median ($\tilde{x}$) = 1.00 , Standard Deviation (s) = 0.77 Test of Significance: H_o: μ ≥ 1.65, H_a: μ < 1.65 The test results are statistically significant at α = 0.05 (P-value = 0.0392).
Concluding Remarks: • The leader-member relationship at the respondent sample and the population of research personnel is almost good. • The conflict of commands at the respondent sample and the population of research personnel tend to be rare. • The participation in decision making among the respondent sample and the population of research personnel is almost few participation. • The recognition of job description by the employees at the respondent sample and the population of research personnel tend to be done through self-learning manner.

Table (6.65): Managerial System of Research Community

Section Three: Characteristics of Technological Team Capabilities

– *Technological Absorptive Capacity*

NO.	VARIABLE	SCALE				
III.3.1	Absorptive Capacity	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
III.3.1.1– III.3.1.4	– Four Sub-variables (See Appendix A)	38	64	138	45	3
Sample Statistics						

Mean ($\bar{x}$) = 2.69	Confidence Interval at 95% : (2.58, 2.80)	Median ($\tilde{x}$) = 3.00	Standard Deviation (s) = 0.92
Test of Significance: H_o: $\mu \geq 2.78$, H_a: $\mu < 2.78$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).			
Concluding Remarks: • The team's absorptive capacity for technology at the respondent sample and the population of research personnel tends to be at moderate degree.			

Table (6.66): Technological Absorptive Capacity of Research Community

– *Conceptualization Capability*

NO.	VARIABLE	SCALE				
III.3.2	Conceptualization Capability	Very Low (1)	Low (2)	Moderate (3)	High (4)	V. High (5)
III.3.2.1–III.3.2.5	– Five Sub-variables (See Appendix A)	26	112	157	60	5

Sample Statistics			
Mean ($\bar{x}$) = 2.74	Confidence Interval at 95% : (2.65, 2.83)	Median ($\tilde{x}$) = 3.00	Standard Deviation (s) = 0.87
Test of Significance: H_o: $\mu \geq 2.82$, H_a: $\mu < 2.82$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0406).			
Concluding Remarks: • The team's conceptualization capability at the respondent sample and the population of research personnel tends to be at moderate degree.			

Table (6.67): Conceptualization Capability of Research Community

Section Four: Issues Critical to Technological Development

– *Barriers to Successful R&D Projects*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
III.4.1	Barriers to Successful R&D Projects	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
III.4.1.1–III.4.1.17	– Seventeen Sub-variables (See Appendix A)	408	371	275	121	49

Sample Statistics			
Mean ($\bar{x}$) = 3.79	Confidence Interval at 95% : (3.73, 3.85)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 1.13
Test of Significance: H_o: $\mu \geq 3.85$, H_a: $\mu < 3.85$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0314).			
Concluding Remarks: • Barriers to successful R&D projects tend to be existed to high extent at both the respondent sample and the population of research community.			

Table (6.68): Barriers to Successful R&D Projects at Research Community

– *Barriers to Technology Development*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
III.4.2	Barriers to Technology Development	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)
III.4.2.1–III.4.2.11	– Eleven Sub-variables (See Appendix A)	182	425	119	60	6

Sample Statistics			
Mean ($\bar{x}$) = 3.90	Confidence Interval at 95% : (3.84, 3.97)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 0.86
Test of Significance: H_o: $\mu \geq 3.96$, H_a: $\mu < 3.96$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0250).			
Concluding Remarks: • Existence of barriers to developing Libyan petroleum technology has clear consensus of both the respondent sample and the population of research community.			

Table (6.69): Barriers to Technology Development at Research Community

– *Priorities for Technological Change*

NO.	VARIABLE		
III.4.3	Key Elements for Technology Development	Rank	Score
III.4.3.1	– Increasing government institutional support to R&D.	1	1.000
III.4.3.2	– More funding for R&D projects.	2	0.888
III.4.3.3	– Improving R&D infrastructure.	3	0.777
III.4.3.4	– Increasing interactions between national oil companies and universities and research institutes.	4	0.666
III.4.3.5	– Enhancing individual interest in R&D through spreading innovation culture.	5	0.555
III.4.3.6	– Formulating effective technology development strategy for Libyan oil sector.	5	0.555
III.4.3.7	– Promoting managerial system of Libyan oil industry.	7	0.333
III.4.3.8	– Motivating native research personnel.	8	0.222
III.4.3.9	– Enhancing foreign partnership/collaboration in local R&D activities.	9	0.111

Concluding Remarks:

- Increasing government institutional support to R&D and more funding for R&D projects are respectively the utmost priorities for technological change in Libyan petroleum sector with respect to the respondent sample of research community.
- Enhancing individual interest in R&D and formulating effective strategy for technology development have equally the middle attention of the respondent sample of research community for technological change in Libyan petroleum sector.
- Motivating native research personnel and enhancing foreign partnership/collaboration have respectively less attention of the respondent sample of research community for technological change in Libyan petroleum sector.

Table (6.70): Priorities for Technological Change at Research Community

6.3.4 Technological Interaction of Foreign Oil Companies

Section One: The Organization Profile

NO.	ITEM	DESCRIPTION
IV.1.1	Target Population	34 foreign companies of producing oil and tech services
IV.1.2	Respondents	21 Companies (61.8%)

Table (6.71): Target Population and Respondents of Foreign Oil Companies

– *Business Type*

NO.	VARIABLE	Company	%
IV.1.3	Business Type		
IV.1.3.1	– Petroleum Exploration	20	95.2
IV.1.3.2	– Petroleum Production	20	95.2
IV.1.3.3	– Oil Refining	5	23.8
IV.1.3.4	– Petrochemical Manufacturing	5	23.8
IV.1.3.5	– Gas Processing	8	38.0
IV.1.3.6	– Chemical Manufacturing	5	23.8

Table (6.72): Business Type of Foreign Oil Companies

– *Company Size*

NO.	VARIABLE	≤ 50 persons	> 50 - ≤ 500	> 1000 – ≤ 2000	> 2000 – ≤ 5000	> 5000 – ≤ 10000	> 10000
IV.1.4	Company Size						
IV.1.4.1	Company's Libya Branch	16	5	-	-	-	-
		76.2 %	23.8 %	-	-	-	-
IV.1.4.2	Parent Company	-	-	5	2	4	10
		-	-	23.8%	9.5%	19.1%	47.6%

Table (6.73): Company Size of Foreign Oil Companies

– *Company Age*

NO.	VARIABLE	≤ 5 yrs	> 5 to ≤ 15 yrs	> 15 to ≤ 30 yrs	> 30 yrs
IV.1.5	Company Age				
IV.1.5.1	No. of Companies	14	3	2	2
		66.7%	14.3%	%9.5	%9.5

Table (6.74): Company Age of Foreign Oil Companies

– *Respondent Profile*

NO.	VARIABLE	Company	%
IV.1.6	Respondent Profile		
IV.1.6.1	– Managing Director	9	42.8
IV.1.6.2	– Member of Executive Board	1	4.7
IV.1.6.3	– Planning Manager	1	4.7
IV.1.6.4	– Engineering Manager	2	9.5
IV.1.6.5	– Operations Manager	5	23.8
IV.1.6.6	– Finance Manager	2	9.5
IV.1.6.7	– Administrative Manager	3	14.3
IV.1.6.8	– Business Development Manager	1	4.7

Table (6.75): Respondent Profile of Foreign Oil Companies

Section Two: Involvement in Foreign Direct Investment (FDI)

– *Type of Foreign Direct Investment*

NO.	VARIABLE	Available	%	To be Available	%	None	%
IV.2.1	Type of Foreign Direct Investment						
IV.2.1.1	– Petroleum R&D	5	23.8	2	9.5	14	66.7

IV.2.1.2	– Petroleum Exploration	21	100	0	0	0	0
IV.2.1.3	– Petroleum Production	6	28.6	14	66.7	1	4.7
IV.2.1.4	– Oil Refining	0	0	1	4.7	20	95.3
IV.2.1.5	– Petrochemical Manufacturing	0	0	2	9.5	19	90.5
IV.2.1.6	– Gas Processing	2	9.5	8	38.1	11	52.4
IV.2.1.7	– Technical Oil Servicing	3	14.3	1	4.7	17	81.0
IV.2.1.8	– Field Chemicals Manufacturing	2	9.5	0	0	19	90.5

Sample Statistics

Petroleum R&D		
– Available	Proportion ($\hat{p}$) = 0.238	– Confidence Interval at 95% : (0.124, 0.352) – Test of Significance: H_o: $p \geq 0.415$, H_a: $p < 0.415$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– To be Available	Proportion ($\hat{p}$) = 0.095	– Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: $p \geq 0.251$, H_a: $p < 0.251$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.667	– Confidence Interval at 95% : (0.540, 0.793) – Test of Significance: H_o: $p \geq 0.809$, H_a: $p < 0.809$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Petroleum Production		
– Available	Proportion ($\hat{p}$) = 0.286	– Confidence Interval at 95% : (0.165, 0.407) – Test of Significance: H_o: $p \geq 0.466$, H_a: $p < 0.466$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– To be Available	Proportion ($\hat{p}$) = 0.667	– Confidence Interval at 95% : (0.540, 0.793) – Test of Significance: H_o: $p \geq 0.809$, H_a: $p < 0.809$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).

– None	Proportion ($\hat{p}$) = 0.047	– Confidence Interval at 95% : (0.00, 0.104) – Test of Significance: H_o: $p \geq 0.190$, H_a: $p < 0.190$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).
Oil Refining – To be Available – None	 Proportion ($\hat{p}$) = 0.047 Proportion ($\hat{p}$) = 0.953	 – Confidence Interval at 95% : (0.00, 0.104) – Test of Significance: H_o: $p \geq 0.190$, H_a: $p < 0.190$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475). – Confidence Interval at 95% : (0.896, 1.00) – Test of Significance: H_o: $p \geq 0.990$, H_a: $p < 0.990$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446).
Petrochemical Manufacturing – To be Available – None	 Proportion ($\hat{p}$) = 0.095 Proportion ($\hat{p}$) = 0.905	 – Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: $p \geq 0.251$, H_a: $p < 0.251$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495). – Confidence Interval at 95% : (0.826, 0.984) – Test of Significance: H_o: $p \geq 0.969$, H_a: $p < 0.969$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0455).
Gas Processing – Available – To be Available – None	 Proportion ($\hat{p}$) = 0.095 Proportion ($\hat{p}$) = 0.381 Proportion ($\hat{p}$) = 0.524	 – Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: $p \geq 0.251$, H_a: $p < 0.251$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495). – Confidence Interval at 95% : (0.251, 0.511) – Test of Significance: H_o: $p \geq 0.562$, H_a: $p < 0.562$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446). – Confidence Interval at 95% : (0.390, 0.658) – Test of Significance: H_o: $p \geq 0.691$, H_a: $p < 0.691$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Technical Oil Servicing		

– Available	Proportion ($\hat{p}$) = 0.143	– Confidence Interval at 95% : (0.049, 0.237) – Test of Significance: H_o: p ≥ 0.309, H_a: p < 0.309. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
– To be Available	Proportion ($\hat{p}$) = 0.047	– Confidence Interval at 95% : (0.000, 0.104) – Test of Significance: H_o: p ≥ 0.190, H_a: p < 0.190. The test results are statistically significant at α = 0.05 (P-value = 0.0475).
– None	Proportion ($\hat{p}$) = 0.810	– Confidence Interval at 95% : (0.705, 0.915) – Test of Significance: H_o: p ≥ 0.912, H_a: p < 0.912. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
Field Chemicals Manufacturing		
– Available	Proportion ($\hat{p}$) = 0.095	– Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: p ≥ 0.251, H_a: p < 0.251. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.905	– Confidence Interval at 95% : (0. 826, 0.984) – Test of Significance: H_o: p ≥ 0.969, H_a: p < 0.969. The test results are statistically significant at α = 0.05 (P-value = 0.0455).

Concluding Remarks:

- 100% of the respondent sample of foreign oil companies in Libya is involved in petroleum exploration activities.
- Only 9.5% of the respondent sample of foreign oil companies in Libya is involved in gas processing activities, and probably at less than 25.1% with respect to the population.
- 66.7% of the respondent sample of foreign oil companies in Libya will involve in petroleum production activities in the future, and probably at less than 80.9% with respect to the population.
- Only 4.7% of the respondent sample of foreign oil companies in Libya will involve in oil refining activities in the future, and probably at less than 19% with respect to the population.
- 90.5% of the respondent sample of foreign oil companies in Libya neither is involved nor will be involved in petrochemical manufacturing activities, and probably at less than 96.9% with respect to the population.
- 81% of the respondent sample of foreign oil companies in Libya neither is involved nor will be involved in technical oil services, and probably at less than 91.2% with respect to the population.

Table (6.76): Types of Foreign Direct Investment in Libyan Oil Sector

– *Modes of Entry for Foreign Direct Investment*

NO.	VARIABLE	Available	%	To be Available	%	None	%
IV.2.2	Modes of Entry for FDI						
IV.2.2.1	– Acquisition of ready-established oil firms.	0	0	6	28.6	15	71.4
IV.2.2.2	– Acquisition of ready-established oil laboratories.	1	4.7	2	9.5	18	85.7
IV.2.2.3	– Petroleum production sharing agreement.	18	85.7	3	14.3	0	0
IV.2.2.4	– Technical oil servicing joint ventures.	1	4.7	5	23.8	15	71.4
IV.2.2.5	– Establishing new firms of technical servicing.	0	0	2	9.5	19	90.5
IV.2.2.6	– Establishing new laboratories of technical servicing.	0	0	4	19.0	17	81.0
IV.2.2.7	– Establishing new R&D laboratories.	0	0	5	23.8	16	76.2

Sample Statistics		
Acquisition of Ready-established Oil Firms – To be Available	Proportion ($\hat{p}$) = 0.286	– Confidence Interval at 95% : (0.165, 0.407) – Test of Significance: H_o: p ≥ 0.466, H_a: p < 0.466. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.714	– Confidence Interval at 95% : (0.593, 0.835) – Test of Significance: H_o: p ≥ 0.845, H_a: p < 0.845. The test results are statistically significant at α = 0.05 (P-value = 0.0485).
Acquisition of Ready-established Oil Lab. – Available	Proportion ($\hat{p}$) = 0.047	– Confidence Interval at 95% : (0.000, 0.104) – Test of Significance: H_o: p ≥ 0.190, H_a: p < 0.190. The test results are statistically significant at α = 0.05 (P-value = 0.0475).

– To be Available	Proportion ($\hat{p}$) = 0.095	– Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: $p \geq 0.251$, H_a: $p < 0.251$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.857	– Confidence Interval at 95% : (0.763, 0.951) – Test of Significance: H_o: $p \geq 0.942$, H_a: $p < 0.942$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446).
Petroleum Production Sharing Agreement.		
– Available	Proportion ($\hat{p}$) = 0.857	– Confidence Interval at 95% : (0.763, 0.951) – Test of Significance: H_o: $p \geq 0.942$, H_a: $p < 0.942$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0446).
– To be Available	Proportion ($\hat{p}$) = 0.143	– Confidence Interval at 95% : (0.049, 0.237) – Test of Significance: H_o: $p \geq 0.309$, H_a: $p < 0.309$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
Technical Servicing Joint Ventures.		
– Available	Proportion ($\hat{p}$) = 0.047	– Confidence Interval at 95% : (0.000, 0.104) – Test of Significance: H_o: $p \geq 0.190$, H_a: $p < 0.190$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0475).
– To be Available	Proportion ($\hat{p}$) = 0.238	– Confidence Interval at 95% : (0.124, 0.352) – Test of Significance: H_o: $p \geq 0.415$, H_a: $p < 0.415$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.714	– Confidence Interval at 95% : (0.593, 0.835) – Test of Significance: H_o: $p \geq 0.845$, H_a: $p < 0.845$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Establishing New Firms of T. Servicing.		
– To be Available	Proportion ($\hat{p}$) = 0.095	– Confidence Interval at 95% : (0.016, 0.174) – Test of Significance: H_o: $p \geq 0.251$, H_a: $p < 0.251$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.905	– Confidence Interval at 95% : (0.826, 0.984) – Test of Significance: H_o: $p \geq 0.969$, H_a: $p <$

		0.969. The test results are statistically significant at α = 0.05 (P-value = 0.0455).
Establishing New Lab. of T. Servicing.		
– To be Available	Proportion ($\hat{p}$) = 0.190	– Confidence Interval at 95% : (0.085, 0.295) – Test of Significance: H_o: p ≥ 0.363, H_a: p < 0.363. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.810	– Confidence Interval at 95% : (0.705, 0.915) – Test of Significance: H_o: p ≥ 0.912, H_a: p < 0.912. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
Establishing New R&D Laboratories.		
– To be Available	Proportion ($\hat{p}$) = 0.238	– Confidence Interval at 95% : (0.124, 0.352) – Test of Significance: H_o: p ≥ 0.415, H_a: p < 0.415. The test results are statistically significant at α = 0.05 (P-value = 0.0495)
– None	Proportion ($\hat{p}$) = 0.762	– Confidence Interval at 95% : (0.648, 0.876) – Test of Significance: H_o: p ≥ 0.880, H_a: p < 0.880. The test results are statistically significant at α = 0.05 (P-value = 0.0485).

Concluding Remarks:

- 85.7% of the respondent sample of foreign oil companies in Libya is involved in activities of FDI in terms of petroleum production sharing agreement, and probably at less than 94.2% with respect to the population.
- Only 4.7% of the respondent sample of foreign oil companies in Libya is involved in activities of FDI in terms of joint ventures of technical oil servicing, and probably at less than 19% with respect to the population.
- 28.6% of the respondent sample of foreign oil companies in Libya will involve in activities of FDI in terms of acquisition of ready-established oil firms and probably at less than 46.6% with respect to the population.
- Only 9.5% of the respondent sample of foreign oil companies in Libya will involve in activities of FDI in terms of acquisition of ready-established oil laboratories and probably at less than 25.1% with respect to the population.
- 76.2% of the respondent sample of foreign oil companies in Libya neither is involved nor will be involved in activities of FDI in terms of establishing new R&D laboratories, and probably at less than 88.8% with respect to the population.

Table (6.77): Modes of Entry for Foreign Direct Investment in Libyan Oil Sector

– *Barriers to Foreign Direct Investment for Technology Development*

NO.	VARIABLE	Degree of Availability				
IV.2.3	Barriers to FDI for Technology Development	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
IV.2.3.1– IV.2.3.15	– Fifteen Sub-variables (See Appendix A)	26	94	120	44	31
Sample Statistics						
Mean ($\bar{x}$) = 3.13	Confidence Interval at 95% : (3.00, 3.24)	Median ($\tilde{x}$) = 3.00	Standard Deviation (s) = 1.07			
Test of Significance: H_o: $\mu \geq 3.23$, H_a: $\mu < 3.23$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).						
Concluding Remarks: • Existence of barriers to FDI for technology development in Libya tends to be at medium degree for both the respondent sample and the population of foreign oil companies.						

Table (6.78): Barriers to FDI for Technology Development

– *Priorities for Encouraging FDI towards Technology Development*

NO.	VARIABLE		
IV.2.4	Key Elements for Encouraging FDI towards Technology Development	Rank	Score
IV.2.4.1	– Building good international reputation for Libyan research institutes and universities through world-class research outputs.	1	1.000
IV.2.4.2	– Promoting managerial system of Libyan oil industry.	2	0.909
IV.2.4.3	– Improving indigenous R&D infrastructure (i.e., through improving human capabilities and technological facilities).	3	0.818
IV.2.4.4	– Increasing host government institutional support to in-house R&D.	4	0.727
IV.2.4.5	– Increasing host government interest &commitment to encourage FDI in R&D.	5	0.636

IV.2.4.6	– Enhancing native individual interest in R&D through spreading innovation culture.	6	o.545
IV.2.4.7	– Formulating effective sectoral strategy of technology development for Libyan oil industry.	7	0.454
IV.2.4.8	– Enhancing foreign partnership/collaboration with local research institutes.	8	0.364
IV.2.4.9	– Increasing local interactions between oil companies, research institutes and university.	9	0.273
IV.2.4.10	– Motivating foreign direct investment through appropriate local tax policies.	10	0.182
IV.2.4.11	– Strengthening local infrastructure of finance institutions.	11	0.091

Concluding Remarks:

- Building good international reputation, promoting managerial system of Libyan oil industry, and improving indigenous R&D infrastructure are respectively the utmost priorities for encouraging FDI towards technology development in Libyan petroleum sector with respect to the respondent sample of foreign oil companies.
- Increasing host government interest & commitment to encourage FDI in R&D, enhancing native individual interest in R&D, and formulating effective sectoral strategy of technology development have respectively the middle attention of the respondent sample of foreign oil companies for encouraging FDI towards technology development in Libyan petroleum sector.
- Increasing local interactions, motivating foreign direct investment, and strengthening local infrastructure of finance institutions have respectively less attention of the respondent sample of foreign oil companies for encouraging FDI towards technology development in Libyan petroleum sector.

Table (6.79): Priorities for Encouraging FDI towards Technology Development

6.3.5 Technological Interaction of Public Universities & Research institutes

Section One: The Organization Profile

NO.	ITEM	DESCRIPTION
V.1.1	Target Population	Six organizations (Four universities and two research institutes)
V.1.2	Respondents	Four organizations (67%)

Table (6.80): Target Population and Respondents of Public Universities and Research Institutes

– *Business Type*

NO.	VARIABLE	Organization	%
V.1.3	Business Type		
V.1.3.1	– University	2	50.0
V.1.3.2	– Research Institute	2	50.0

Table (6.81): Business Type of Organizations

– *Organization Size*

NO.	VARIABLE	≤ 200 employees	> 200 - ≤ 500	> 500 - ≤ 1500	> 3000 - ≤ 4400
V.1.4	Organization Size				
V.1.4.1	No. of Organizations	1	1	1	1
		25.0%	25.0%	25.0%	25.0%

Table (6.82): Organization Size of Public Universities and Research Institutes

– *Organization Age*

NO.	VARIABLE	> 5 to ≤ 10 yrs	> 20 to ≤ 30 yrs	> 40 yrs
V.1.5	Organization Age			
V.1.5.1	No. of Organizations	2	1	1
		50.0%	25.0%	25.0%

Table (6.83): Organization Age of Public Universities and Research Institutes

– *Organization Ownership*

NO.	VARIABLE	Organization	%
V.1.6	Organization Ownership		
V.1.6.1	– Public Ownership	4	100
V.1.6.2	– Shared Ownership	0	0

Table (6.84): Organization Ownership of Public Universities and Research Institutes

– *Respondent Profile*

NO.	VARIABLE	Organization	%
V.1.7	Respondent Profile		
V.1.7.1	– Faculty of Engineering Dean	1	25.0
V.1.7.2	– Member of University Scientific Committee	2	50.0
V.1.7.3	– Research Institute Chairman	1	25.0
V.1.7.4	– Member of Institute Scientific Committee	1	25.0

Table (6.85): Respondent Profile of Public Universities and Research Institutes

Section Two: Characteristics of Technological Activities

– *Involvement in Research and Development*

NO.	VARIABLE	Available	%	To be Available	%	None	%
V.2.1	Basic Research	4	100	0	0	0	0
V.2.2	Applied Research	1	25.0	3	75.0		
V.2.3 V.2.3.1– V.2.3.8	Experimental Development – Eight Sub-variables (See Appendix A)	3	9.4	12	37.5	17	53.1

Sample Statistics		
Applied Research –Available	Proportion ($\hat{p}$) = 0.250	– Confidence Interval at 95% : (0.000, 0.518) – Test of Significance: H_o: p ≥ 0.645, H_a: p < 0.645. The test results are statistically significant at α = 0.05 (P-value = 0.0495).
–To be Available	Proportion ($\hat{p}$) = 0.750	– Confidence Interval at 95% : (0.482, 1.000) – Test of Significance: H_o: p ≥ 0.943, H_a: p < 0.943. The test results are statistically significant at α = 0.05 (P-value = 0.0485).

Experimental Development – Available	Proportion ($\hat{p}$) = 0.09	– Confidence Interval at 95% : (0.035, 0.153) – Test of Significance: H_o: $p \geq 0.214$, H_a: $p < 0.214$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).
– To be Available	Proportion ($\hat{p}$) = 0.375	– Confidence Interval at 95% : (0.277, 0.473) – Test of Significance: H_o: $p \geq 0.521$, H_a: $p < 0.521$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.531	– Confidence Interval at 95% : (0.430, 0.632) – Test of Significance: H_o: $p \geq 0.669$, H_a: $p < 0.669$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).
Concluding Remarks: • 25% of the respondent sample of public universities and research institutes is involved in applied research activities, and probably at less than 64.5% with respect to the population. • 75% of the respondent sample of public universities and research institutes will involve in applied research activities, and probably at less than 94.3% with respect to the population. • 9.4% of experimental development activities are carried out by the respondent sample of public universities and research institutes, and probably at less than 21.4% with respect to the population. • 37.5% of experimental development activities will be carried out by the respondent sample of public universities and research institutes, and probably at less than 52.1% with respect to the population. • 53.1% of experimental development activities neither carried out nor will be carried out by the respondent sample of public universities and research institutes, and probably at less than 66.9% with respect to the population.		

Table (6.86): Involvement of Public Universities and Research Institutes in R&D

– *Research and Development Priorities*

NO.	VARIABLE		
V.2.4	R&D Priorities	Rank	Score
V.2.4.1	– Increasing Stock of Knowledge	1	1.00
V.2.4.2	– Meeting Globalization Challenges	2	0.923
V.2.4.3	– Problem Solving for Technical Operations	3	0.846

V.2.4.4	– Developing International Outlook	4	0.769
V.2.4.5	– Targeting Strategic Technological Opportunities	5	0.692
V.2.4.6	– Reduction of Production Cost	6	0.615
V.2.4.7	– Building Technological Self-reliance	7	0.538
V.2.4.8	– Introducing Novel or Improved Process	8	0.461
V.2.4.9	– Enhancing Productivity of Technical Operations	9	0.385
V.2.4.10	– Waste Reduction	10	0.308
V.2.4.11	– Meeting Technology Demand	11	0.231
V.2.4.12	– Competition Purpose	12	0.154
V.2.4.13	– Introducing Novel or Improved Product	13	0.077

Concluding Remarks:

- Increasing of stock knowledge, meeting globalization challenges, and problem solving for technical operations are respectively the utmost priorities of R&D at the respondent sample of public universities and research institutes.
- Reduction of production cost, building technological self-reliance, and introducing novel or improved process have respectively the middle attention of R&D at the respondent sample of public universities and research institutes.
- Meeting technology demand, competition purpose, and introducing novel or improved product have respectively the least attention of R&D at the respondent sample of public universities and research institutes.

Table (6.87): R&D Priorities at Public Universities and Research Institutes

Section Three: Issues Critical to Technological Development

– *Barriers to Successful R&D Projects*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
V.3.1	Barriers to Successful R&D Projects	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
V.3.1.1– V.3.1.15	– Fifteen Sub-variables (See Appendix A)	19	17	12	9	3
Sample Statistics						

Mean ($\bar{x}$) = 3.67	Confidence Interval at 95% : (3.35, 3.98)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 1.22
Test of Significance: H_o: $\mu \geq 3.94$, H_a: $\mu < 3.94$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0436).			
Concluding Remarks: • Barriers to successful R&D projects tend to be existed to high extent at both the respondent sample and the population of public universities and research institutes.			

Table (6.88): Barriers to Successful R&D Projects at Public Universities and Research Institutes

– *Priorities for Technological Change*

NO.	VARIABLE		
V.3.2	Key Elements for Technology Development	Rank	Score
V.3.2.1	– More funding for R&D projects.	1	1.000
V.3.2.2	– Increasing interactions between national oil companies, research institutes and universities.	2	0.888
V.3.2.3	– Improving R&D infrastructure.	3	0.777
V.3.2.4	– Increasing government institutional support to R&D.	4	0.666
V.3.2.5	– Enhancing individual interest in R&D through spreading innovation culture.	5	0.555
V.3.2.6	– Formulating effective technology development strategy for Libyan oil sector.	6	0.444
V.3.2.7	– Enhancing foreign partnership/collaboration in local R&D activities.	7	0.333
V.3.2.8	– Promoting managerial system of Libyan oil industry.	7	0.222
V.3.2.9	– Motivating native research personnel.	9	0.111
Concluding Remarks: • More funding for R&D projects, increasing interactions between national oil companies, research institutes and universities are respectively the utmost priorities for technological change in Libyan petroleum sector with respect to the respondent sample of public universities and research institutes. • Enhancing individual interest in R&D, and formulating effective technology development			

strategy have respectively the middle attention of the respondent sample of public universities and research institutes for technological change in Libyan petroleum sector.

- Promoting managerial system of Libyan oil industry and motivating native research personnel have respectively less attention of the respondent sample of public universities and research institutes for technological change in Libyan petroleum sector.

Table (6.89): Priorities for Technological Change at Public Universities and Research Institutes

6.3.6 Technological Interaction of Private Companies of Technical Oil Services

Section One: The Organization Profile

NO.	ITEM	DESCRIPTION
VI.1.1	Target Population	15 companies of technical oil services
VI.1.2	Respondents	8 companies (54%)

Table (6.90): Target Population and Respondents of Private Companies of Technical Oil Services

– *Business Type*

NO.	VARIABLE	Company	%
VI.1.3	Business Type		
VI.1.3.1	– Petroleum Exploration Services	3	37.5
VI.1.3.2	– Petroleum Production Services	2	25.0
VI.1.3.3	– Oil Refining Services	0	0
VI.1.3.4	– Petrochemical Services	0	0
VI.1.3.5	– Gas Processing Services	0	0
VI.1.3.6	– Maintenance Support	6	75.0
VI.1.3.7	– Training & Consultation Services	4	50.0
VI.1.3.8	– Construction Services	2	25.0
VI.1.3.9	– Material supply	6	75.0

Table (6.91): Business Type of Private Companies of Technical Oil Services

– *Company Size*

NO.	VARIABLE	≤ 10 persons	> 10 – ≤ 30	> 70 – ≤ 90
VI.1.4	Company Size			
VI.1.4.1	No. of Companies	2	5	1
		25.0%	62.5%	12.5%

Table (6.92): Company Size of Private Companies of Technical Oil Services

– *Company Age*

NO.	VARIABLE	≤ 10 yrs	> 10 to ≤ 15 yrs	> 15 to ≤ 20 yrs
VI.1.5	Company Age			
VI.1.5.1	No. of Companies	6	1	1
		75%	12.5%	12.5%

Table (6.93): Company Age of Private Companies of Technical Oil Services

– *Company Ownership*

NO.	VARIABLE	Company	%
VI.1.6	Company Ownership		
VI.1.6.1	– Private Ownership	8	100
VI.1.6.2	– Shared Ownership	0	0

Table (6.94): Company Ownership of Private Companies of Technical Oil Services

– *Respondent Profile*

NO.	VARIABLE	Company	%
VI.1.7	Respondent Profile		
VI.1.7.1	– Company Chairman	6	75.0
VI.1.7.2	– Engineering Manager	1	12.5
VI.1.7.3	– Projects Manager	1	12.5

Table (6.95): Respondent Profile of Private Companies of Technical Oil Services

Section Two: Characteristics of Technological Activities

– *Work Dependency*

<table>
<tr><th>NO.</th><th>VARIABLE</th><th colspan="8">IMPLEMENTATION MODE</th></tr>
<tr><td>VI.2.1</td><td>Work Dependency</td><td>I.H.</td><td>%</td><td>N.C.</td><td>%</td><td>F.C.</td><td>%</td><td>None</td><td>%</td></tr>
<tr><td>VI.2.1.1 – VI.2.1.3</td><td>– Three Sub-variables (See Appendix A)</td><td>11</td><td>45.8</td><td>10</td><td>41.6</td><td>15</td><td>62.5</td><td>6</td><td>25</td></tr>
<tr><td colspan="10">Sample Proportions</td></tr>
<tr><td>– I.H.</td><td>Proportion ($\hat{p}$) = 0.458</td><td colspan="8">– Confidence Interval at 95% : (0.320, 0.596)
– Test of Significance: H_o: $p \geq 0.622$, H_a: $p < 0.622$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0490).</td></tr>
<tr><td>– N.C.</td><td>Proportion ($\hat{p}$) = 0.416</td><td colspan="8">– Confidence Interval at 95% : (0.280, 0.552)
– Test of Significance: H_o: $p \geq 0.582$, H_a: $p < 0.582$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).</td></tr>
<tr><td>– F.C</td><td>Proportion ($\hat{p}$) = 0.625</td><td colspan="8">– Confidence Interval at 95% : (0.491, 0.759)
– Test of Significance: H_o: $p \geq 0.768$, H_a: $p < 0.768$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0485).</td></tr>
<tr><td>– None</td><td>Proportion ($\hat{p}$) = 0.250</td><td colspan="8">– Confidence Interval at 95% : (0.130, 0.370)
– Test of Significance: H_o: $p \geq 0.416$, H_a: $p < 0.416$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).</td></tr>
<tr><td colspan="10">Concluding Remarks:
• 45.8% of the respondent sample of private companies of technical oil services is dependent on their own technical capabilities to perform the target activities, and probably at less than 62.2% with respect to the population.
• 41.6% of the respondent sample of private companies of technical oil services is dependent on national collaboration to perform the target activities, and probably at less than 58.2% with respect to the population.
• 62.5% of the respondent sample of private companies of technical oil services is dependent on foreign collaboration to perform the target activities, and probably at less than 76.8% with respect to the population.</td></tr>
</table>

• 25% of the respondent sample of private companies of technical oil services does not perform some of target activities, and probably at less than 41.6% with respect to the population.

Table (6.96): Work Dependency of Private Companies of Technical Oil Services

– *Involvement in Research and Development*

NO.	VARIABLE	Available	%	To be Available	%	None	%
VI.2.2	Basic Research	1	12.5	0	0	6	75.0
VI.2.3	Applied Research	1	12.5	0	0		

Sample Statistics		
Basic Research – Available	Proportion ($\hat{p}$) = 0.125	– Confidence Interval at 95% : (0.000, 0.287) – Test of Significance: H_o: $p \geq 0.412$, H_a: $p < 0.412$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
Applied Research – Available	Proportion ($\hat{p}$) = 0.125	– Confidence Interval at 95% : (0.000, 0.287) – Test of Significance: H_o: $p \geq 0.412$, H_a: $p < 0.412$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).
– None	Proportion ($\hat{p}$) = 0.750	– Confidence Interval at 95% : (0.538, 0.962) – Test of Significance: H_o: $p \geq 0.914$, H_a: $p < 0.914$. The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0495).

Concluding Remarks: • 12.5% of the respondent sample of private companies of technical oil services is involved in basic research activities, and probably at less than 41.2% with respect to the population. • 12.5% of the respondent sample of private companies of technical oil services is involved in applied research activities, and probably at less than 41.2% with respect to the population. • 75% of the respondent sample of private companies of technical oil services neither is involved nor will be involved in research activities, and probably at less than 91.4% with respect to the population.

Table (6.97): Involvement of Private Companies of Technical Oil Services in R&D

– *The Company Support to Research Activities*

NO.	VARIABLE	SUPPORTING MODE			
VI.2.4	Supporting Research Activities	Regularly (4)	Occasionally (3)	Rarely (2)	None (1)
VI.2.4.1– VI.2.4.8	– Eight Sub-variables (See Appendix A)	2	2	1	59
Sample Statistics					
Mean ($\bar{x}$) = 1.17	Confidence Interval at 95% : (1.01, 1.33)	Median ($\tilde{x}$) = 1.00	Standard Deviation (s) = 0.63		
Test of Significance: H_o: $\mu \geq 1.31$, H_a: $\mu < 1.31$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0375).					
Concluding Remarks: • Supporting research activities is almost not existed at both the respondent sample and the population of private companies of technical oil services.					

Table (6.98): Supporting of Private Companies of Technical Oil Services to Research Activities

– *Barriers to Supporting Technology Development*

NO.	VARIABLE	DEGREE OF AVAILABILITY				
VI.2.5	Barriers to Supporting Technology Development	Very High (5)	High (4)	Medium (3)	Low (2)	None (1)
VI.2.5.1– VI.2.5.12	– Twelve Sub-variables (See Appendix A)	47	15	13	14	7
Sample Statistics						
Mean ($\bar{x}$) = 3.84	Confidence Interval at 95% : (3.57, 4.12)	Median ($\tilde{x}$) = 4.00	Standard Deviation (s) = 1.36			
Test of Significance: H_o: $\mu \geq 4.08$, H_a: $\mu < 4.08$ The test results are statistically significant at $\alpha = 0.05$ (P-value = 0.0418).						
Concluding Remarks: • Barriers to supporting technology development in Libya tend to be highly existed at both the respondent sample and the population of private companies of technical oil services.						

Table (6.99): Barriers to Supporting Technology Development at Private Companies

– *Priorities for Supporting R&D*

NO.	VARIABLE		
VI.2.6	Key Elements for Technology Development	Rank	Score
VI.2.6.1	– Formulating effective strategy of technology development for Libyan oil sector.	1	1.000
VI.2.6.2	– Improving national R&D infrastructure.	2	0.888
VI.2.6.3	– Offering opportunities to national companies of oil services to expand their profits.	3	0.777
VI.2.6.4	– Increasing government interest & commitment to encourage R&D.	4	0.666
VI.2.6.5	– Promoting managerial system of Libyan oil industry.	5	0.555
VI.2.6.6	– Increasing local interactions between oil companies and research institutes and universities.	6	0.444
VI.2.6.7	– Enhancing individual interest in R&D through spreading innovation culture.	7	0.333
VI.2.6.8	– Increasing government institutional support to in-house R&D.	8	0.222
VI.2.6.9	– Building good international reputation for Libyan research institutes and universities through world-class outputs.	9	0.111

Concluding Remarks:

- Formulating effective strategy for technology development, and improving national R&D infrastructure are respectively the utmost priorities for supporting R&D with respect to the respondent sample of private companies of technical oil services.
- Increasing government interest & commitment to encourage R&D, promoting managerial system of Libyan oil industry, and increasing local interactions have respectively the middle attention of the respondent sample of private companies of technical oil services for supporting R&D.
- Increasing government institutional support to in-house R&D and building good international reputation have respectively less attention of the respondent sample of private companies of technical oil services for supporting R&D.

Table (6.100): Priorities for Supporting R&D at Private Companies of Technical Oil Services

6.4 EXPLORING DIFFERENCES AND ASSOCIATIONS

6.4.1 Differences of Characteristics of Technological Capabilities

– *Comparison of Characteristics of Technological Capabilities*

VARIABLES	Libyan Petroleum Institute			National Oil Companies		
	μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S
– Inward Technology Transfer	3.75	4.00	0.71	2.98	3.00	0.92

VARIABLES	LPI			National Oil Companies		
	A. (%)	T. B. A. (%)	N. (%)	A. (%)	T. B. A. (%)	N. (%)
– Involvement in R&D						
▪ Basic Research	0	100	0	28.6	0	42.8
▪ Applied Research	100	0	0	42.8	0	
▪ Experimental Development	12.5	87.0	0	8.9	17.8	73.3

VARIABLES	Libyan Petroleum Institute				National Oil Companies			
	I.H. (%)	N.C. (%)	F.C. (%)	N. (%)	I.H. (%)	N.C. (%)	F.C. (%)	N. (%)
– R&D Dependency	30.0	50.0	20.0	0	42.8	7.1	10	57.1
– Competence for Technological Assimilation	83.3	0	16.7	0	40.3	13.3	37.2	42.3
– Characteristics of Training and Development	0	12	100	0	20.2	22.6	49.4	30.3

VARIABLES	Libyan Petroleum Institute		National Oil Companies	
	Availability		Availability	
	Yes (%)	No (%)	Yes (%)	No (%)
– Structure of R&D Facilities				
▪ Physical Facilities	100	0	42.9	57.1
▪ Intellectual Facilities	66.7	33.3	35.7	64.3

A.: Available *T.B.A.: To be Available* *N.: None*

Table (6.101): Comparison of Characteristics of Technological Capabilities

– *Hypothesis Testing for Differences of Characteristics of Tech. Capabilities*

VARIABLE	HYPOTHESIS TEST
– Inward Technology Transfer	– H_o: μ_{CO} = 3.75 (i.e., The population mean of inward technology transfer at national oil companies equals the population mean of inward technology transfer at Libyan petroleum institute) – H_a: $\mu_{CO} \neq 3.75$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (t = -6.263) is larger than the critical test value ($t_{(0.025,55)} = -2.004$), we reject the null hypothesis and conclude that the population mean of inward technology transfer at national oil companies is not equal to the population mean of inward technology transfer at Libyan petroleum institute.
– Involvement in R&D	
▪ Basic Research	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of involvement in basic research at national oil companies equals the proportion in the population of involvement in basic research at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value ($\chi^2 = 6.000$) is larger than the critical test value ($\chi^2_{(0.05,2)} = 5.991$), we reject the null hypothesis and conclude that the proportion in the population of involvement in basic research at national oil companies is not equal to the proportion in the population of involvement in basic research at Libyan petroleum institute.
▪ Applied Research	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of involvement in applied research at national oil companies equals the proportion in the population of involvement in applied research at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are not statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value ($\chi^2 = 0.875$) is less than the critical test value ($\chi^2_{(0.05,2)} = 5.991$), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that the proportion in the population of involvement in applied research at national oil companies equals the proportion in the population of involvement in applied

	research at Libyan petroleum institute.
▪ Experimental Development	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of involvement in experimental development at national oil companies equals the proportion in the population of involvement in experimental development at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at α = 0.05. – *Interpretation:* Since the calculated test value (χ^2 = 18.734) is larger than the critical test value ($\chi^2_{(0.05,2)}$ = 5.991), we reject the null hypothesis and conclude that the proportion in the population of involvement in experimental development at national oil companies is not equal to the proportion in the population of involvement in experimental development at Libyan petroleum institute.
– R&D Dependency	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of R&D dependency at national oil companies equals the proportion in the population of R&D dependency at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at α = 0.05. – *Interpretation:* Since the calculated test value (χ^2 = 21.988) is larger than the critical test value ($\chi^2_{(0.05,3)}$ = 7.815), we reject the null hypothesis and conclude that the proportion in the population of R&D dependency at national oil companies is not equal to the proportion in the population of R&D dependency at Libyan petroleum institute.
– Competence for Technological Assimilation	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of competence for technological assimilation at national oil companies equals the proportion in the population of competence for technological assimilation at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at α = 0.05. – *Interpretation:* Since the calculated test value (χ^2 = 28.879) is larger than the critical test value ($\chi^2_{(0.05,3)}$ = 7.815), we reject the null hypothesis and conclude that the proportion in the population of competence for technological assimilation at national oil companies is not equal to the proportion in the population of competence for technological assimilation at Libyan petroleum institute.
– Characteristics of Training and	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of characteristics of training and development at national oil

Development	companies equals the proportion in the population of characteristics of training and development at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value ($\chi^2 = 25.215$) is larger than the critical test value ($\chi^2_{(0.05,3)} = 7.815$), we reject the null hypothesis and conclude that the proportion in the population of characteristics of training and development at national oil companies is not equal to the proportion in the population of characteristics of training and development at Libyan petroleum institute.
– Structure of R&D Facilities	
▪ Physical Facilities	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of structure of R&D physical facilities at national oil companies equals the proportion in the population of structure of R&D physical facilities at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value ($\chi^2 = 9.143$) is larger than the critical test value ($\chi^2_{(0.05,1)} = 3.841$), we reject the null hypothesis and conclude that the proportion in the population of structure of R&D physical facilities at national oil companies is not equal to the proportion in the population of structure of R&D physical facilities at Libyan petroleum institute.
▪ Intellectual Facilities	– H_o: $P_{CO} = P_{LPI}$ (i.e., The proportion in the population of structure of R&D intellectual facilities at national oil companies equals the proportion in the population of structure of R&D intellectual facilities at Libyan petroleum institute) – H_a: $P_{CO} \neq P_{LPI}$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value ($\chi^2 = 4.206$) is larger than the critical test value ($\chi^2_{(0.05,1)} = 3.841$), we reject the null hypothesis and conclude that the proportion in the population of structure of R&D intellectual facilities at national oil companies is not equal to the proportion in the population of structure of R&D intellectual facilities at Libyan petroleum institute.

Table (6.102): Hypothesis Testing for Differences of Characteristics of Technological Capabilities

6.4.2 Differences of Issues Critical to Technological Development

– *Comparison of Issues Critical to Technological Development*

Libyan Petroleum Institute			National Oil Companies			Research Community			Universities & Research Institutes		
Significance of Petroleum Technology Development											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
1.00	-	-	2.00	2.00	1.00	-	-	-	-	-	-
Barriers to Successful R&D Projects											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
3.88	3.00	0.99	3.90	4.00	0.98	3.79	4.00	1.13	3.67	4.00	1.22
Barriers to Technology Development											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
4.91	5.00	0.30	3.96	4.00	0.75	3.90	4.00	0.86	-	-	-
Role of Government towards Technology Development											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
2.07	2.00	0.26	2.11	2.00	0.73	-	-	-	-	-	-
Interaction with National Universities & Research Institutes											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
2.39	2.00	1.24	1.95	2.00	0.85	-	-	-	-	-	-
Interaction with Foreign Universities & Research Institutes											
μ	$\tilde{\mu}$	σ	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S	$\bar{x}$	$\tilde{x}$	S
2.62	3.00	1.20	1.69	1.00	0.87	-	-	-	-	-	-

Table (6.103): Comparison of Issues Critical to Technological Development

– *Hypothesis Testing for Differences of Issues Critical to Tech. Development*

VARIABLE	HYPOTHESIS TEST
– Significance of Petroleum Technology Development	– H_o: $\mu_{CO} = 1.00$ (i.e., The population mean of significance of petroleum technology development at national oil companies equals the population mean of significance of petroleum technology development at Libyan petroleum institute) – H_a: $\mu_{CO} \neq 1.00$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (t = 2.646) is larger than the critical test value ($t_{(0.025,6)} = 2.447$), we reject the null hypothesis and conclude that the population mean of significance of petroleum technology development at national oil companies is not equal to the population mean of significance of petroleum technology development at Libyan petroleum institute.
– Barriers to Successful R&D Projects	– H_o: $\mu_{CO} = \mu_{RC} = \mu_{UN} = \mu_{LPI}$ (i.e., The population means of barriers to successful R&D projects at national oil companies, research community, universities/research institutes, and Libyan petroleum institute are all equal) – H_a: $\mu_{CO} \neq \mu_{RC} \neq \mu_{UN} \neq \mu_{LPI}$ – The test results are not statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (F = 0.646) is less than the critical test value ($F_{(0.05,\ 3,\ 1416)} = 2.6$), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that the population means of barriers to successful R&D projects at national oil companies, research community, universities/research institutes, and Libyan petroleum institute are all equal.
– Barriers to Technology Development	– H_o: $\mu_{CO} = \mu_{RC} = \mu_{LPI}$ (i.e., The population means of barriers to technology development at national oil companies, research community, and Libyan petroleum institute are all equal) – H_a: $\mu_{CO} \neq \mu_{RC} \neq \mu_{LPI}$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (F = 7.827) is larger than the critical test value ($F_{(0.05,\ 2,\ 877)} = 3.00$), we reject the null hypothesis and conclude that the population means of barriers to technology development at national oil companies, research community, and Libyan petroleum institute are not all equal.

– Role of Government towards Technology Development	– H_o: μ_{CO} = 2.07 (i.e., The population mean of role of government towards technology development at national oil companies equals the population mean of role of government towards technology development at Libyan petroleum institute) – H_a: $\mu_{CO} \neq 2.07$ – The test results are not statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (t = 0.542) is less than the critical test value ($t_{(0.025,97)}$ = 1.985), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that the population mean of role of government towards technology development at national oil companies equals the population mean of role of government towards technology development at Libyan petroleum institute.
– Interaction with National Universities/ Research Institutes	– H_o: μ_{CO} = 2.39 (i.e., The population mean of interaction with national universities/research institutes at national oil companies equals the population mean of interaction with national universities/research institutes at Libyan petroleum institute) – H_a: $\mu_{CO} \neq 2.39$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (t = 5.810) is larger than the critical test value ($t_{(0.025,125)}$ = 1.984), we reject the null hypothesis and conclude that the population mean of interaction with national universities/research institutes at national oil companies does not equal the population mean of interaction with national universities/research institutes at Libyan petroleum institute.
– Interaction with Foreign Universities/ Research Institutes	– H_o: μ_{CO} = 2.62 (i.e., The population mean of interaction with foreign universities/ research institutes at national oil companies equals the population mean of interaction with foreign universities/ research institutes at Libyan petroleum institute) – H_a: $\mu_{CO} \neq 2.62$ – The test results are statistically significant at $\alpha = 0.05$. – *Interpretation:* Since the calculated test value (t = -11.999) is less than the critical test value ($t_{(0.025,125)}$ = -1.984), we reject the null hypothesis and conclude that the population mean of interaction with foreign universities/ research institutes at national oil companies does not equal the population mean of interaction with foreign universities/ research institutes at Libyan petroleum institute.

Table (6.104): Hypothesis Testing for Differences of Issues Critical to Technological Development

6.4.3 Associations of Technological Absorptive Capacity

The issue of absorptive capacity has gained recently considerable interest as a key organizational resource for technological change (see, for instance, Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Vanden Bosch et al., 1999; Newey and Shulman, 2004; Nieto and Quevedo, 2005). This concept remains a vital area for research as the organizational influences have not been fully acknowledged. A set of organizational determinants that may influence the absorptive capacity as being a dependent variable is statistically investigated using regression analysis with separate models for each of the independent variables because of *"collinearity"* effect. The relevant hypotheses are tested using data of technological competency of research community illustrated in section 6.3.3 (pp.221-232).

Figure 6.1 shows the structured framework of hypothesis testing of organizational influences on team's absorptive capacity.

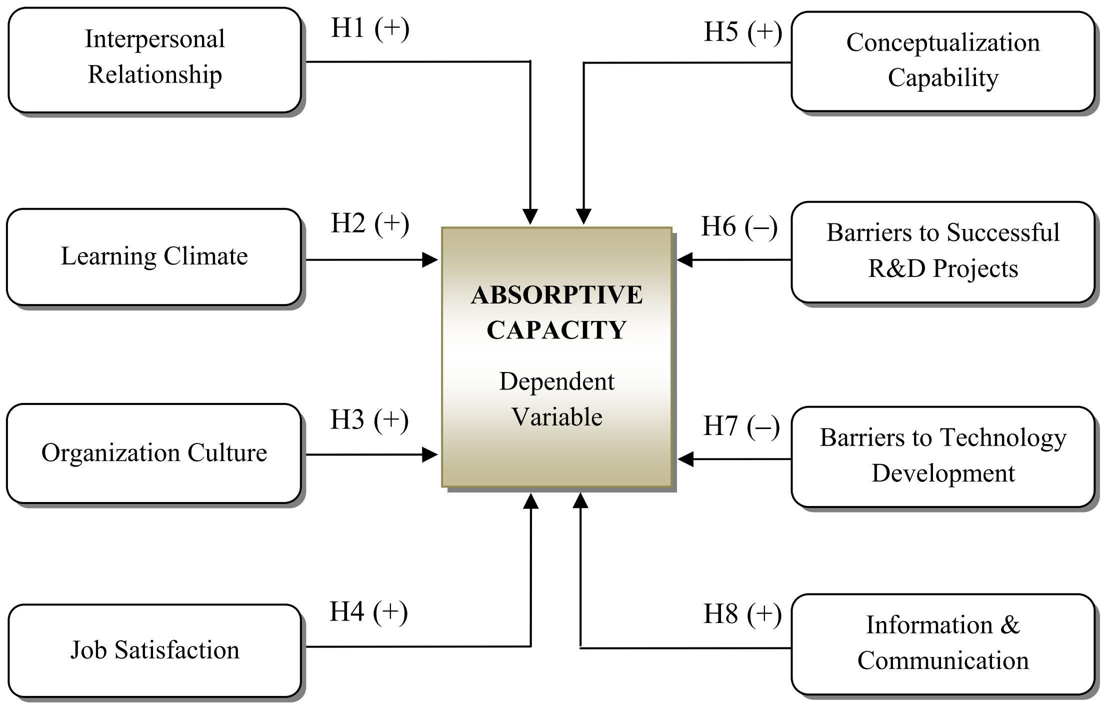


Figure (6.1): Structured Framework of Various Organizational Influences on Absorptive Capacity

The investigation process of various organizational influences on absorptive capacity will take place as follows:

– *Description of Alternative Hypothesis*

ALTERNATIVE HYPOTHESIS	DESCRIPTION
H1	The interpersonal relationships influence positively the team's absorptive capacity.
H2	The learning climate influences positively the team's absorptive capacity.
H3	The organization culture influences positively the team's absorptive capacity.
H4	The job satisfaction influences positively the team's absorptive capacity.
H5	The conceptualization capability influences positively the team's absorptive capacity.
H6	The barriers to successful R&D influence negatively the team's absorptive capacity.
H7	The barriers to technology development influence negatively the team's absorptive capacity.
H8	The information and communication process influences positively the team's absorptive capacity.

Table (6.105): Hypothesis Description of Various Organizational Influences on Absorptive Capacity

– *Correlation of Variables*

	Job Satisfaction	**Interpersonal Relationships**	**Information & Communication**	**Organization Culture**	**Learning Climate**	**Absorptive Capacity**	**Conceptualization Capacity**	**Barriers to R&D**	**Barriers to Tech. Development**
	1	2	3	4	5	6	7	8	9
1	+ 1.000								
2	+ **0.947*** *(0.015)*	+ 1.000							
3	+ **0.910*** *(0.032)*	+ **0.976**** *(0.004)*	+ 1.000						
4	+	+	+	+					

	0.975** *(0.005)*	**0.933*** *(0.021)*	**0.903*** *(0.036)*	1.000					
5	+ 0.098 *(0.875)*	+ 0.169 *(0.786)*	+ 0.275 *(0.654)*	+ 0.299 *(0.625)*	+ 1.000				
6	– 0.028 *(0.965)*	– 0.040 *(0.949)*	+ 0.053 *(0.932)*	+ 0.178 *(0.774)*	+ **0.951*** *(0.013)*	+ 1.000			
7	+ 0.079 *(0.900)*	+ 0.162 *(0.795)*	+ 0.263 *(0.669)*	+ 0.282 *(0.646)*	+ **0.999**** *(0.000)*	+ **0.944*** *(0.016)*	+ 1.000		
8	+ 0.531 *(0.358)*	+ 0.474 *(0.420)*	+ 0.279 *(0.650)*	+ 0.546 *(0.341)*	– 0.163 *(0.794)*	– 0.161 *(0.796)*	– 0.150 *(0.810)*	+ 1.000	
9	+ **0.930*** *(0.022)*	+ 0.825 *(0.086)*	+ 0.715 *(0.174)*	+ **0.892*** *(0.042)*	– 0.110 *(0.861)*	– 0.167 *(0.788)*	– 0.124 *(0.842)*	+ 0.772 *(0.126)*	+ 1.000

* *Correlation significant at α = 0.05 (two-tailed test),* ** *Correlation significant at α = 0.01 (two-tailed test)*

The numbers in parentheses are P-values.

Table (6.106): Pearson Correlation Matrix of Various Organizational Influences

– *Hypothesis Testing of Associations*

VARIABLE	HYPOTHESIS TEST
– Interpersonal Relationships	– $H_o : \beta_1 \leq 0$ (i.e., interpersonal relationships have no influence or negative influence on team absorptive capacity) – $H_1 : \beta_1 > 0$ (i.e., interpersonal relationships influence positively team absorptive capacity) – The test results are not statistically significant at α = 0.05. P-value = 0.949 – *Interpretation:* Since the calculated test value (t = - 0.069) is less than the critical test value ($t_{(0.05,3)}$ = 2.353), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that interpersonal relationships

	influence positively team absorptive capacity.
−Learning Climate	− $H_o : \beta_1 \leq 0$ (i.e., learning climate has no influence or negative influence on team absorptive capacity) − $H_2 : \beta_1 > 0$ (i.e., learning climate influences positively team absorptive capacity) − The test results are statistically significant at $\alpha = 0.05$. P-value = 0.013 − *Interpretation:* Since the calculated test value ($t = 5.348$) is larger than the critical test value ($t_{(0.05,3)} = 2.353$), we reject the null hypothesis and conclude that learning climate influences positively team absorptive capacity.
−Organization Culture	− $H_o : \beta_1 \leq 0$ (i.e., organization culture has no influence or negative influence on team absorptive capacity) − $H_3 : \beta_1 > 0$ (i.e., organization culture influences positively team absorptive capacity) − The test results are not statistically significant at $\alpha = 0.05$. P-value = 0.774 − *Interpretation:* Since the calculated test value ($t = 0.314$) is less than the critical test value ($t_{(0.05,3)} = 2.353$), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that organization culture influences positively team absorptive capacity.
−Job Satisfaction	− $H_o : \beta_1 \leq 0$ (i.e., job satisfaction has no influence or negative influence on team absorptive capacity) − $H_4 : \beta_1 > 0$ (i.e., job satisfaction influences positively team absorptive capacity) − The test results are not statistically significant at $\alpha = 0.05$. P-value = 0.965 − *Interpretation:* Since the calculated test value ($t = -0.048$) is less than the critical test value ($t_{(0.05,3)} = 2.353$), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that job satisfaction influences positively team absorptive capacity.
−Conceptualization Capability	− $H_o : \beta_1 \leq 0$ (i.e., conceptualization capability has no influence or negative influence on team absorptive capacity) − $H_5 : \beta_1 > 0$ (i.e., conceptualization capability influences positively team absorptive capacity) − The test results are statistically significant at $\alpha = 0.05$. P-value = 0.013

	– *Interpretation:* Since the calculated test value (t = 4.967) is larger than the critical test value ($t_{(0.05,3)}$ = 2.353), we reject the null hypothesis and conclude that conceptualization capability influences positively team absorptive capacity.
– Barriers to Successful R&D	– $H_o : \beta_1 \geq 0$ (i.e., barriers to successful R&D have no influence or positive influence on team absorptive capacity) – $H_6 : \beta_1 < 0$ (i.e., barriers to successful R&D influence negatively team absorptive capacity) – The test results are not statistically significant at $\alpha = 0.05$. P-value = 0.796 – *Interpretation:* Since the calculated test value (t = - 0.283) is less than the critical test value ($t_{(0.05,3)}$ = - 2.353), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that barriers to successful R&D influence negatively team absorptive capacity**.**
– Barriers to Technology Development	– $H_o : \beta_1 \geq 0$ (i.e., barriers to technology development have no influence or positive influence on team absorptive capacity) – $H_7 : \beta_1 < 0$ (i.e., barriers to technology development influence negatively team absorptive capacity) – The test results are not statistically significant at $\alpha = 0.05$. P-value = 0.788 – *Interpretation:* Since the calculated test value (t = - 0.294) is less than the critical test value ($t_{(0.05,3)}$ = - 2.353), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that barriers to technology development influence negatively team absorptive capacity**.**
– Information and Communication Process	– $H_o : \beta_1 \leq 0$ (i.e., information and communication process has no influence or negative influence on team absorptive capacity) – $H_8 : \beta_1 > 0$ (i.e., information and communication process influences positively team absorptive capacity) – The test results are not statistically significant at $\alpha = 0.05$. P-value = 0.932 – *Interpretation:* Since the calculated test value (t = 0.093) is less than the critical test value ($t_{(0.05,3)}$ = 2.353), the null hypothesis can not be rejected and the data do not provide sufficient evidence to conclude that information and communication process influences positively team absorptive capacity**.**

Table (6.107): Hypothesis Testing of Various Organizational Influences on Absorptive Capacity

– *Regression Models of Associations*

MODEL 1: $\hat{Y} = -1.50 + 0.82\,X$

Independent Variable (X): Learning Climate

Dependent Variable (Y): Absorptive Capacity

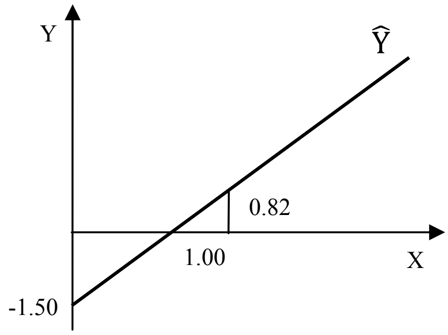
Confidence Interval for β_0 at $\alpha = 0.05$:

(- 44.813, 41.874)

Confidence Interval for β_1 at $\alpha = 0.05$:

(0.332, 1.309)

$R^2 = 0.905$, Adjusted $R^2 = 0.873$, $\Delta R^2 = 0.905$



ANOVA Table 1:

Source	Degree of Freedom	Sum of Squares	Mean Square	F Ratio	P-value
Regression	1	9076.976	9076.976	28.587	0.013
Residual (error)	3	952.224	317.408		
Total	4	10029.200	-		

Conclusion: The learning climate is significantly essential for increasing the team's absorptive capacity.

MODEL 2: $\hat{Y} = 3.04 + 0.76\,X$

Independent Variable (X): Conceptualization Capability

Dependent Variable (Y): Absorptive Capacity

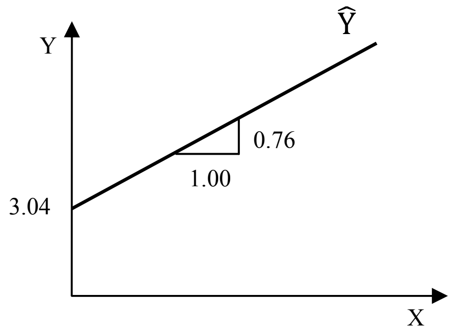
Confidence Interval for β_0 at $\alpha = 0.05$:

(- 41.180, 47.266)

Confidence Interval for β_1 at $\alpha = 0.05$:

(0.272, 1.243)

$R^2 = 0.892$, Adjusted $R^2 = 0.855$, $\Delta R^2 = 0.892$



ANOVA Table 2:

Source	Degree of Freedom	Sum of Squares	Mean Square	F Ratio	P-value
Regression	1	8942.057	8942.057	24.676	0.016
Residual (error)	3	1087.143	362.381		
Total	4	10029.200	-		

Conclusion: The conceptualization capability is significantly essential for increasing the team's absorptive capacity.

6.5 THE RESEARCH FINDINGS

6.5.1 Concluding Results

– *Involvement in Research and Development:* The Libyan petroleum institute (LPI) is mainly involved in applied research activities rather than basic research. Only 12.5% of experimental development activities are carried out in LPI (see table 6.8, p.198). The national oil companies, on the other hand, are involved in both applied and basic research activities, with 28.6% of the respondent sample of national companies is involved in basic research and 42.8% in applied research. Only 8.9% of experimental development activities are carried out by the respondent sample of national oil companies whiles 73.3% neither performed nor will be performed (see table 6.38, p.214). 25% of the respondent sample of public universities and research institutes is involved in applied research and only 9.4% of experimental development activities are carried out by these organizations (see table 6.86, p.252). 75% of the respondent sample of private companies of technical oil services neither involved nor will be involved in research activities (see table 6.97, p.258). Figure 6.2 depicts the percentage of experimental development activities performed, to be performed, or not to be performed by LPI, the respondent samples of national oil companies, public universities and research institutes.

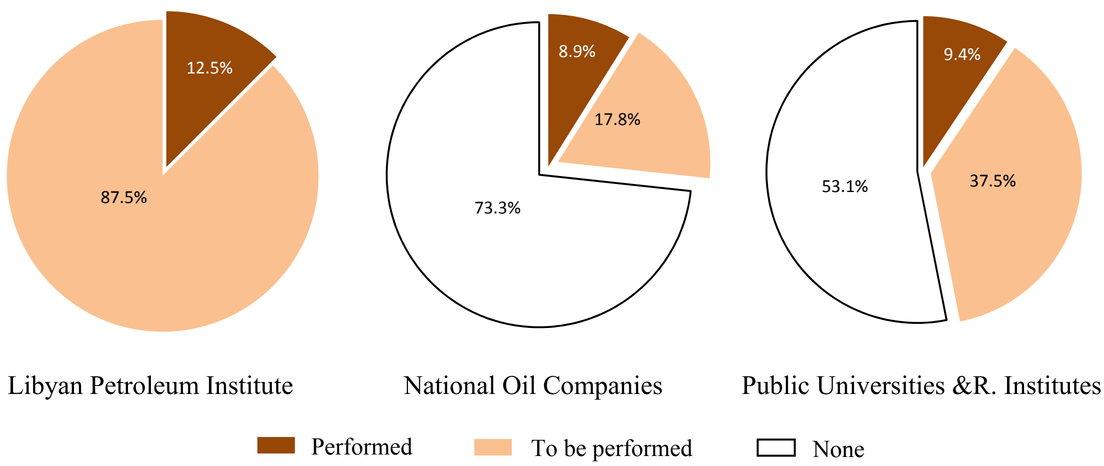


Figure (6.2): Involvement of Key Players of Libyan Oil Sector in Exp. Development Activities

Hence, involvement of LPI, national oil companies, public universities and research institutes, and private companies of technical oil services, in research and development is almost weak.

– *Research and Development Priorities:* The research and development priority scores for LPI and the respondent sample of national oil companies are quite shown in figure 6.3.

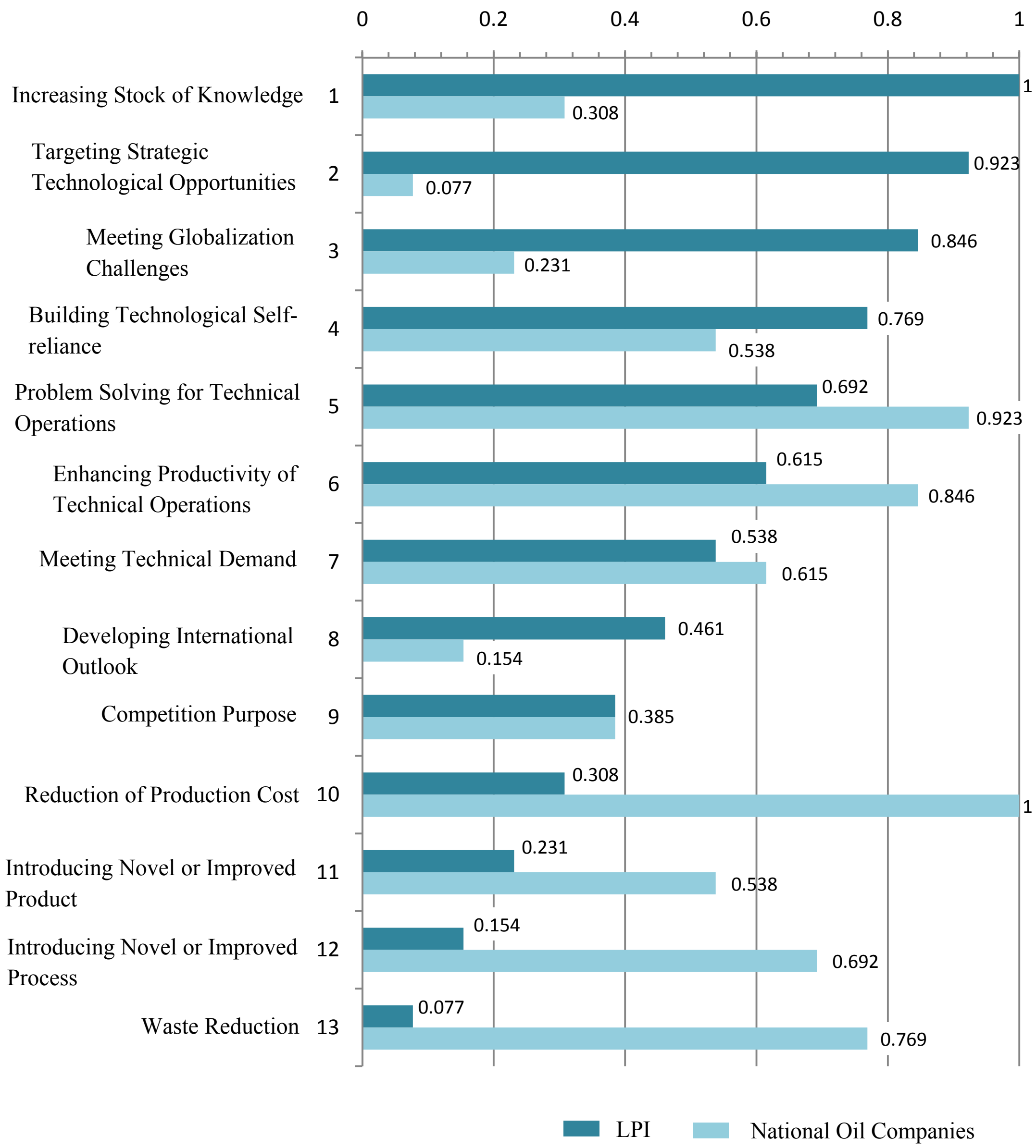


Figure (6.3): R&D Priorities for Libyan Petroleum Institute and National Oil Companies

Increasing stock knowledge, targeting strategic technological opportunities, and meeting globalization challenges are respectively the utmost priorities of R&D at LPI (see table 6.9, p.198), whiles reduction of production cost, problem solving for technical operations, and enhancing productivity of technical operations are respectively the utmost priorities of R&D at the respondent sample of national oil companies (see table 6.39, p.215). In this sense, there is a sort of vision diversion between LPI and national oil companies towards R&D output, where the former looks for strategic technological vision and the latter has an operation-oriented vision. As such, R&D collaboration between both sides might not lead to well-coordinated approach due to existence of different visions. In addition, competition purpose comes at the ninth priority, for both LPI and national oil companies, which indicates that both players are not working under high competition circumstances that entail high involvement in R&D to challenge rivals.

– *Research and Development Dependency:* The Libyan petroleum institute executes 30% of R&D cornerstones by its own technical capabilities, 50% of all these activities along with national collaboration, and only 20%with foreign collaboration (see table 6.10, p.199). Furthermore, 42.8% of the respondent sample of national oil companies is dependent on their own technical capabilities to perform R&D cornerstones, 7.1% on national collaboration, 10% on foreign collaboration, and 57.1% do not perform R&D cornerstones at all (see table 6.40, p.216). Figure 6.4 demonstrates R&D dependency at LPI and national oil companies.

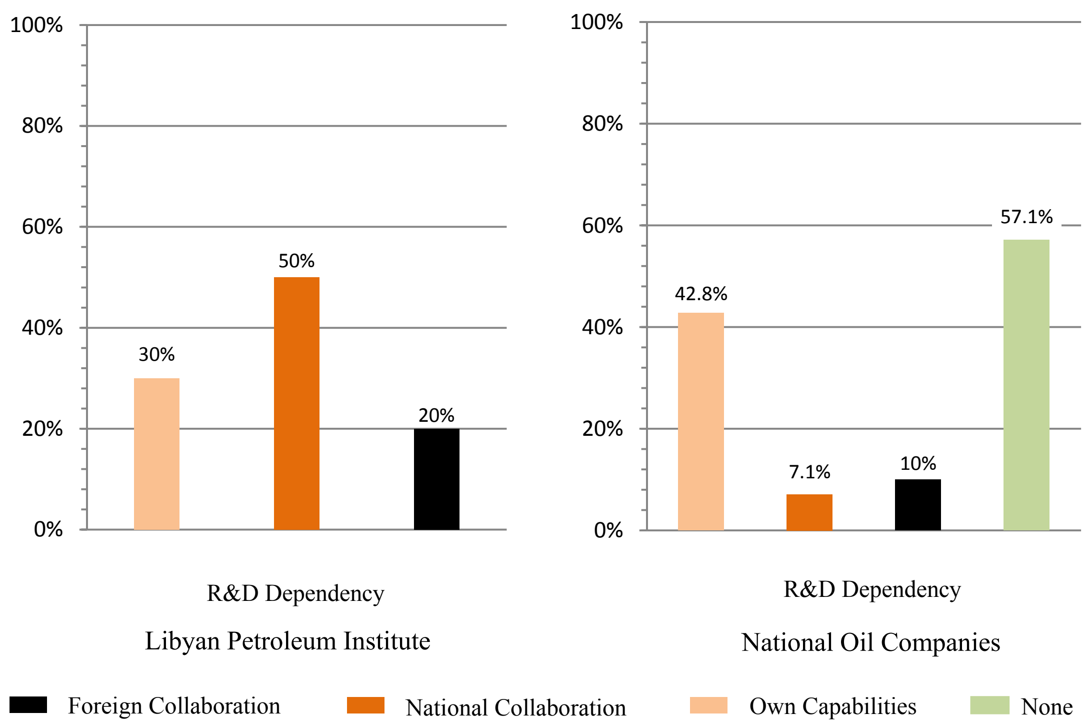


Figure (6.4): R&D Dependency at LPI and National Oil Companies

Thus, LPI is dependent largely on its technical capabilities and on national collaboration to perform R&D cornerstones, whiles national oil companies are less dependent on their own capabilities, and about half of respondent companies do not involve in R&D. This variation of R&D dependency may lead to fundamental inconsistency between those key players. Generally speaking, LPI and national oil companies are both dependent to good extent on their technical capabilities in performing R&D.

– *Generating Research and Development Idea:* Involvement of top management and all researchers of interest with collaboration of other external organizations (i.e., universities, research institutes and consultancies) in generating R&D ideas is regularly occurred in LPI. Involvement of local collaboration and customer request is occasionally performed in generating R&D ideas in LPI, while involvement of government initiatives is rarely considered (see table 6.11, p.200). In addition, 14.3% of the respondent sample of national oil companies generating regularly R&D ideas, 8.6% occasionally, 11.4% rarely, and 65.7% of them do not generate R&D ideas at all (see table 6.41, p.217). Figure 6.5 shows involvement of LPI and national oil companies in generating R&D ideas.

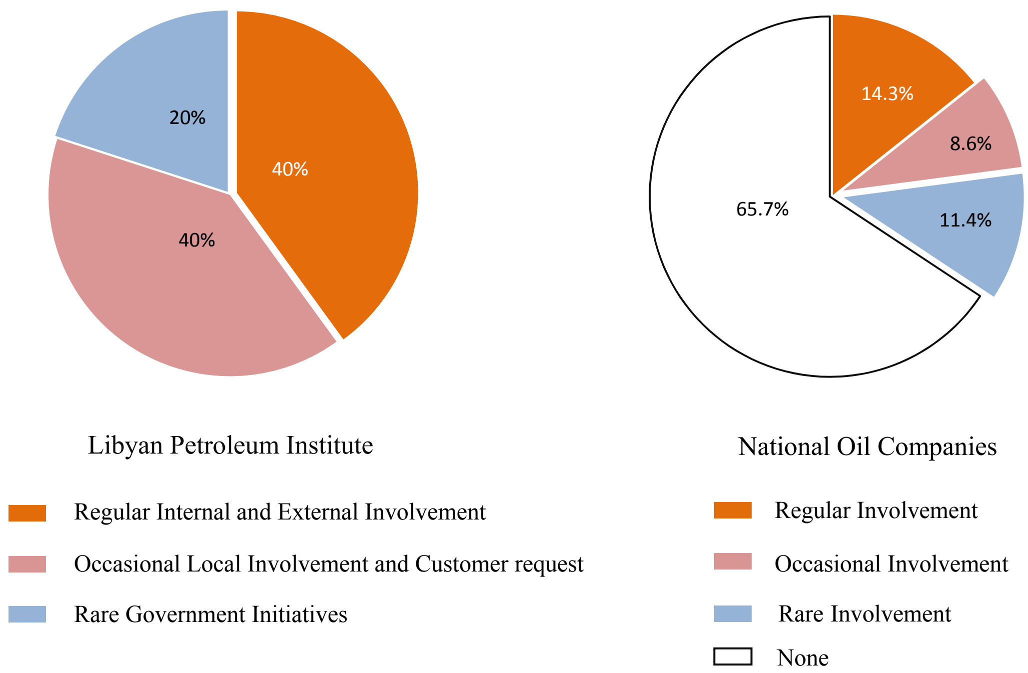


Figure (6.5): Generating R&D Ideas at LPI and National Oil Companies

As a result, LPI depends regularly on internal and external involvement in generating R&D ideas rather than rarely involvement of government. National oil companies show rare interest in generating R&D ideas.

– *Modelling Technology Development:* The interactive model that combines both the science -technology push and market pull is the regular pattern used in technology development endeavours at Libyan petroleum institute (see table 6.12, p.200). Modelling technology development is almost rarely performed at both the respondent sample and the population of national oil companies (see table 6.42, p.217). This indicates that there is no vital interest in technology development at national oil companies based on deliberate modelling.

– *Structure of R&D Facilities:* Physical R&D facilities are more available than intellectual facilities at LPI (see table 6.13, p.201). The respondent sample of national oil companies has possessed 42.9% of physical R&D facilities, and 35.7% of intellectual R&D facilities (see table 6.43, p.218). Figure 6.6 shows structure of R&D facilities at LPI and national oil companies.

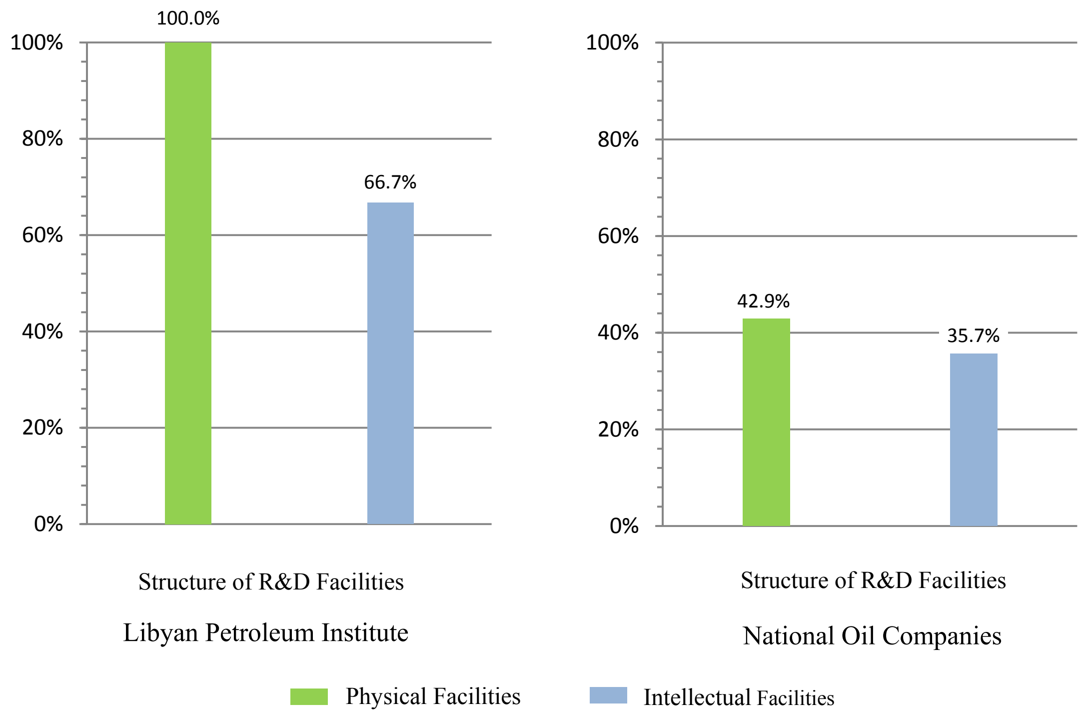


Figure (6.6): Structure of R&D Facilities at LPI and National Oil Companies

Thus, LPI is very well-equipped with R&D physical facilities than national oil companies have. Both key players suffer shortage of R&D intellectual facilities to different degrees.

– *Scientific and Technical Output:* LPI has regular scientific and technical output in terms of research papers, technical studies, technical performance reports and electronic publications. LPI produces occasionally scientific articles, rarely technical bulletins, rarely scientific books, and rarely granted patents. LPI does not have any output regarding technical standards, technical directives, know-how licenses, applied patents, technical copyrights, industrial designs, and trademarks (see table 6.14, p.202). The key elements of presumed scientific and technical output at LPI and national oil companies are shown in figure 6.7.

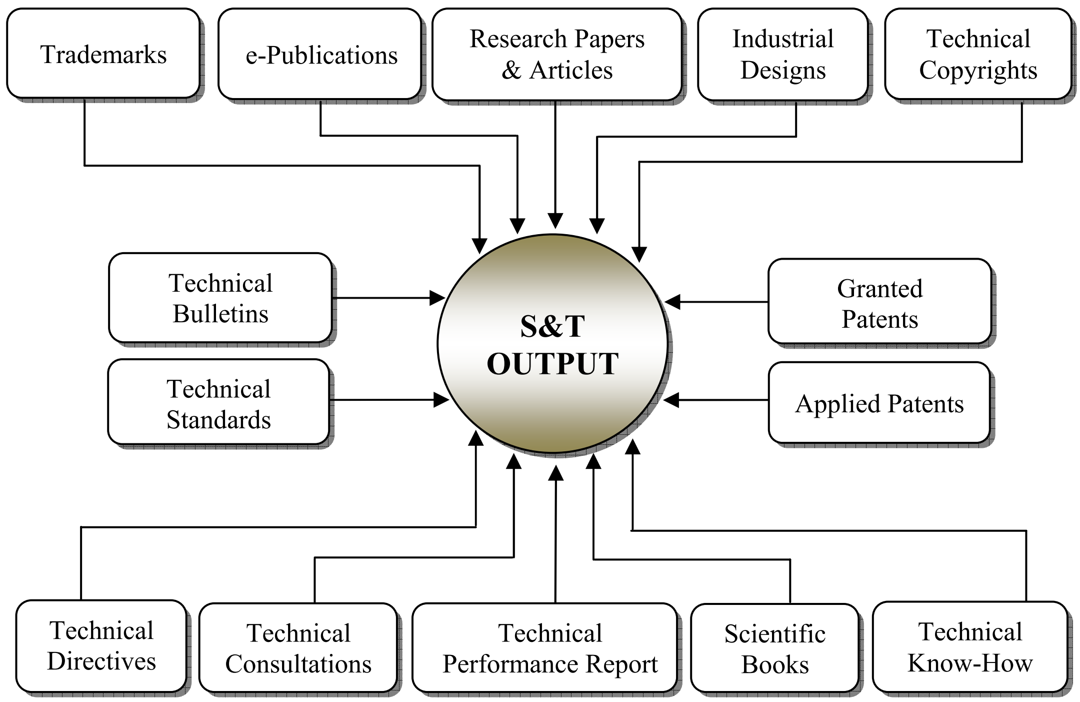


Figure (6.7): Key Elements of Presumed S&T Output at LPI and National Oil Companies

The respondent sample of national oil companies produces regularly 6.1% of scientific and technical output, 13.3% produced occasionally, 28.6% produced rarely, and 52% of presumed scientific and technical output is not produced at all (see table 6.44, p.219). In figure 6.8 (p.280), the scientific and technical output of LPI and national oil companies are clearly demonstrated.

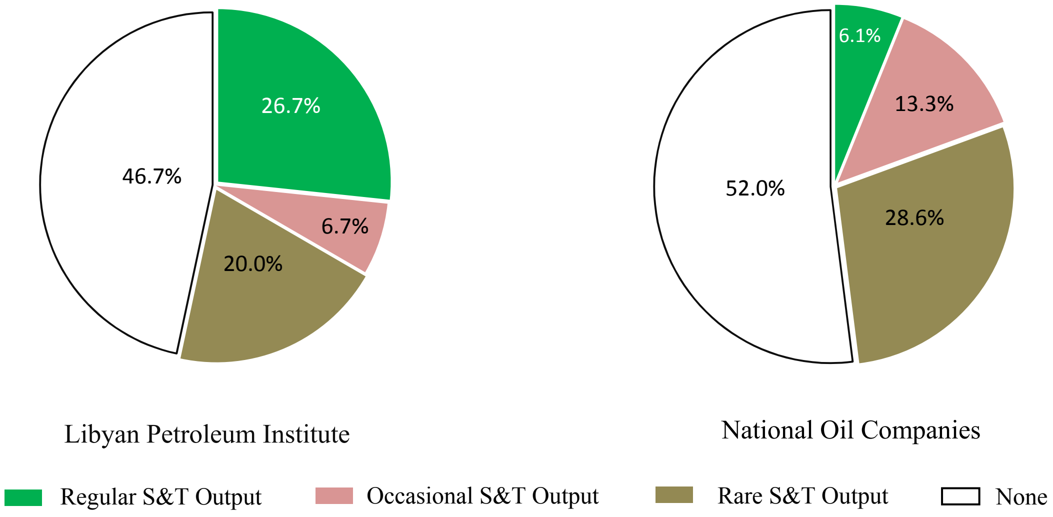


Figure (6.8): Scientific and Technical Output at LPI and National Oil Companies

Thus, LPI and national oil companies focus mainly on elements of knowledge accumulation (i.e., researcher papers, scientific articles, technical studies, technical performance reports electronic publications) rather than producing technology (i.e., technical know-how, applied patents, granted patents). LPI has more regular scientific and technical output than national oil companies. Scientific and technical output of national oil companies is almost rare. Both LPI and national oil companies has no interest in producing about half of presumed technical and scientific output. LPI and national oil companies have weak scientific and technical output.

— *Competency for Technological Assimilation:* At LPI, 83.3% of technology utilization is done by its own technical staff. Only 16.7% is done by foreign collaboration (see table 6.15, p.202). For the respondent sample of national oil companies, 40.3% of petroleum technologies are operated by their own technical capabilities, 13.3% by national collaboration, and 37.2% by foreign collaboration. 42.3% of petroleum technologies are not utilized at the respondent sample of national oil companies either due to lack of accessibility or irrelevancy (see table 6.45, p.220). Technological assimilation of LPI and national oil companies is demonstrated in Figure 6.9 (p.281).

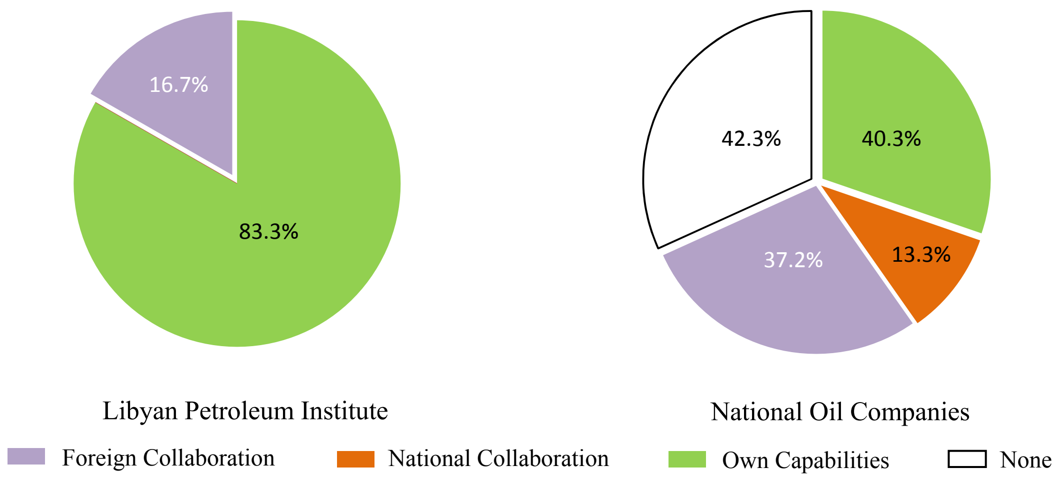


Figure (6.9): Technological Assimilation at LPI and National Oil Companies

In general, competency of LPI to assimilate utilized technology is almost twofold the competency of national oil companies. Thus, overall technology assimilation at technological competence domain of Libyan oil sector is almost good.

– *Inward Technology Transfer:* Technology is almost transferred regularly to Libyan petroleum institute (see table 6.16, p.203). Technology transfer to both the respondent sample and the population of national oil companies is almost performed occasionally (see table 6.46, p.221). As a result, LPI is more open to inward technology transfer than national oil companies, and overall technology transfer to technological competence domain of Libyan oil sector has an occasional rate. Figure 6.10 shows rate of technology transfer into technological competence domain of Libyan oil sector.

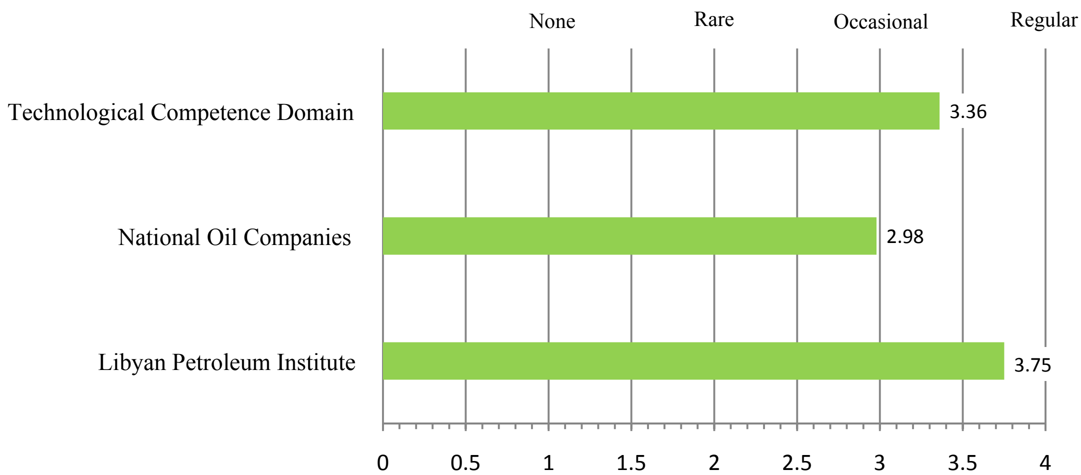


Figure (6.10): Rate of Technology Transfer into Libyan Oil Sector

– *Dependency on Foreign Supplier:* LPI is dependent very high on foreign supplier to acquire machinery, raw material, spare parts and performing training and development. LPI is dependent to medium extent on foreign supplier to get technical support and technical consultation, while dependent very low with respect to technical management (see table 6.17, p.203). Dependency on foreign supplier is almost highly considered at both the respondent sample and the population of national oil companies (see table 6.47, p.221). Figure 6.11 shows dependency on foreign supplier to meet various technological necessities at LPI and mean value of dependency on foreign supplier at national oil companies.

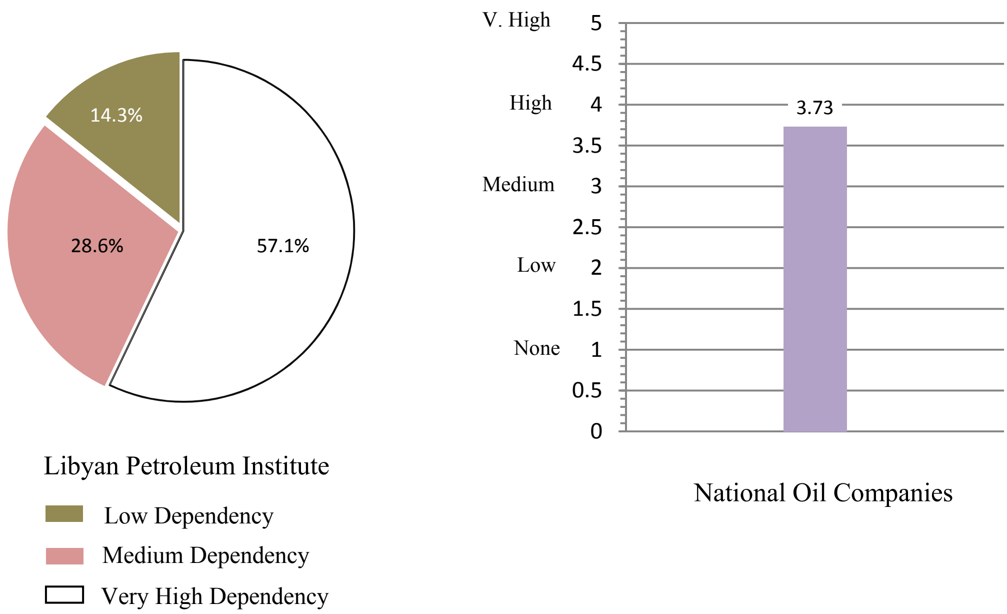


Figure (6.11): Dependency on Foreign Supplier at LPI and National Oil Companies

Therefore, dependency on foreign supplier to meet the technological needs of competence domain of Libyan oil sector is almost high.

– *Characteristics of Training and Development:* 100% of training and development programmes at Libyan petroleum institute are conducted by foreign collaboration and only 12% conducted along with national collaboration (see table 6.18, p.204). At the respondent sample of national oil companies 20.2% of training and development programmes are conducted by in-house capabilities, 22.6% by national collaboration, 49.4 % by foreign collaboration, and 30.3% is not conducted at all (see table 6.48, p.222). Figure 6.12 (p.283) illustrates percentage of conducting training programmes in technological competence domain of Libyan oil sector.

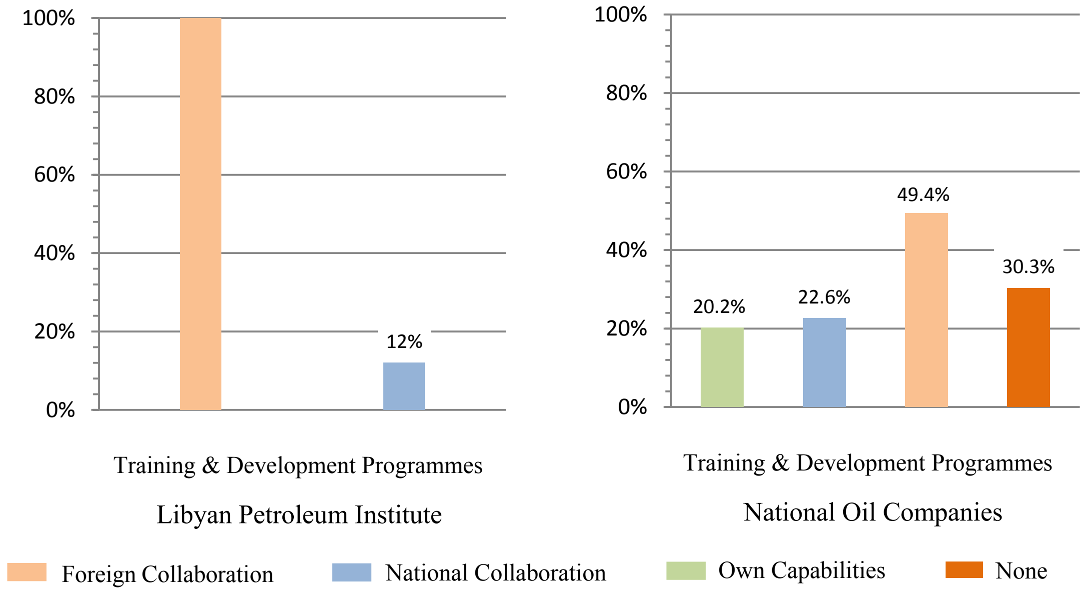


Figure (6.12): Characteristics of Training and Development at Technological Competence Domain

In 2005, 16.7 % of entire workforce of Libyan oil sector has been trained locally and 3.14% abroad. In 2006, 15.94% trained locally and 3.05% abroad. All local training programmes executed between 2002 and 2006 exceeded the targets (Survey data). Figure 6.13 shows numbers of trainees at Libyan oil sector involved in local and abroad training programmes.

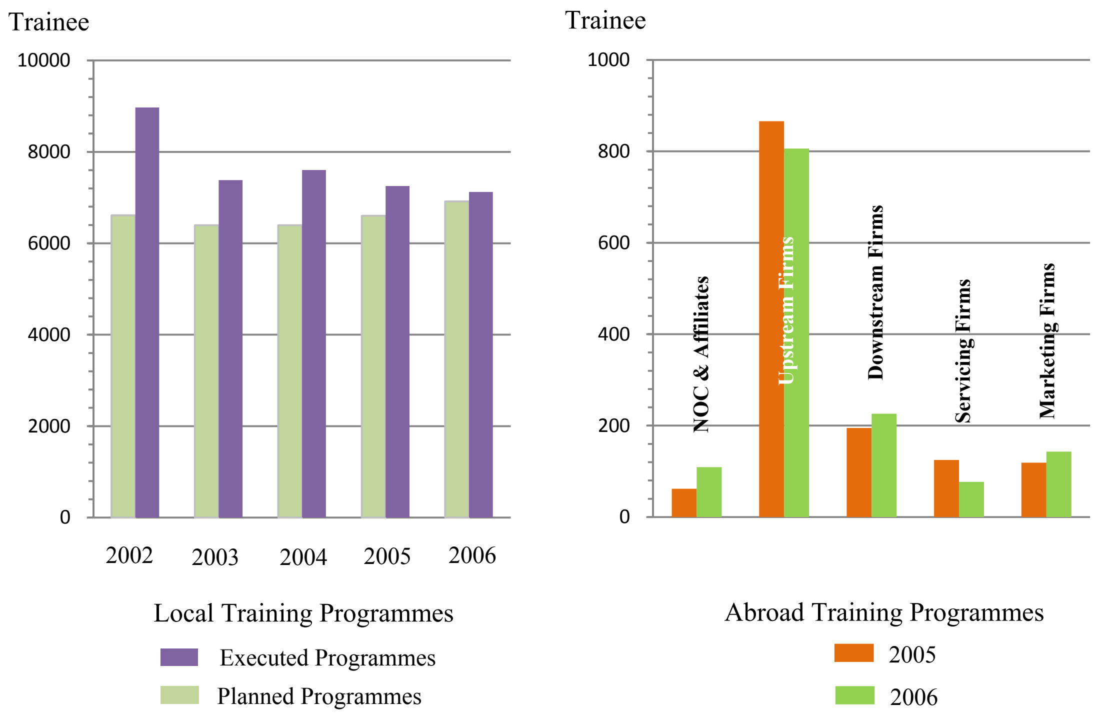


Figure (6.13): Local & Abroad Training Programmes at Libyan Oil Sector

– *Significance of Technology Development:* Significance of petroleum technology development to survival is at low consideration in Libyan petroleum institute. LPI is used to, formulate its own technology strategy, and get involved in efforts of petroleum technology development. LPI has not felt any government commitment or support to set a national or sectoral S&T strategy. LPI has not received any kind of local or international fund (e.g., FDI) towards technology development (see table 6.19, p.205). Significance of technology development to survival has a medium-level of consideration at both the respondent sample and the population of national oil companies. 42.8%of the respondent sample of national oil companies is used to formulate their own strategy of petroleum technology development. 28.6% of the respondent sample of national oil companies is involved in efforts of petroleum technology development. 100% of the respondent sample of national oil companies has not felt any government support to set a national or sectoral S&T strategy. 14.3% of the respondent sample of national oil companies has received some kind of fund for petroleum technology development (see table 6.49, p.224). Hence, technology development is not much significant to technological competence domain of Libyan oil sector. Figure 6.14 demonstrates some indications of significance of technology development at national oil companies.

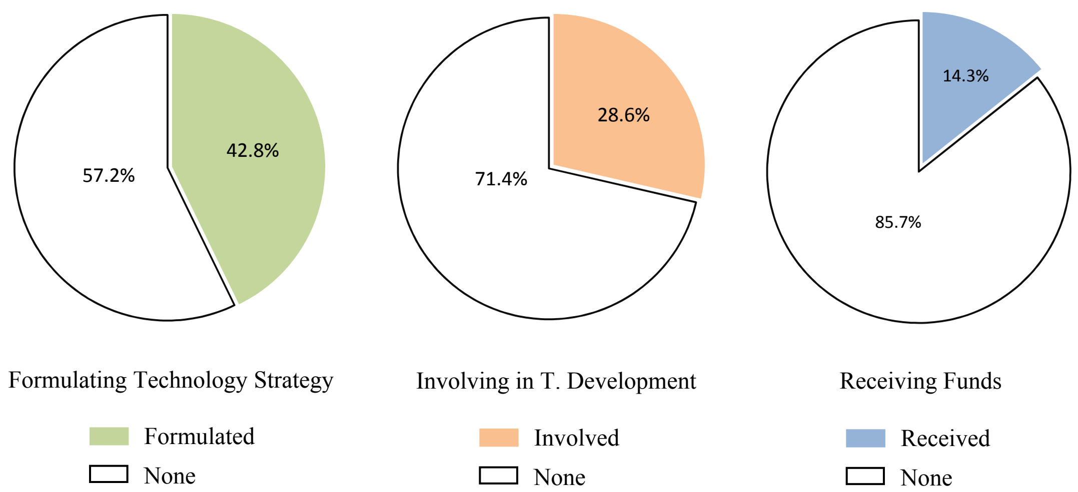


Figure (6.14): Significance of Technology Development at National Oil Companies

– *Barriers to Successful R&D Projects:* At LPI, barriers to successful R&D are almost existed to high extent (see table 6.20, p.205). At both the respondent sample and the population of national oil companies barriers to successful R&D projects are almost existed to high extent (see table 6.50, p.225). At both the respondent sample and the population of research community, barriers to successful R&D projects tend to be existed to high extent (see table 6.68, p.238). At both the respondent sample and the population of public universities and research institutes, barriers to successful R&D projects tend to be existed to high extent (see table 6.88, p.254). Thus, successful R&D projects face barriers to high degree at Libyan oil sector. Figure 6.15 shows the extent to which the Libyan oil sector has barriers to R&D projects.

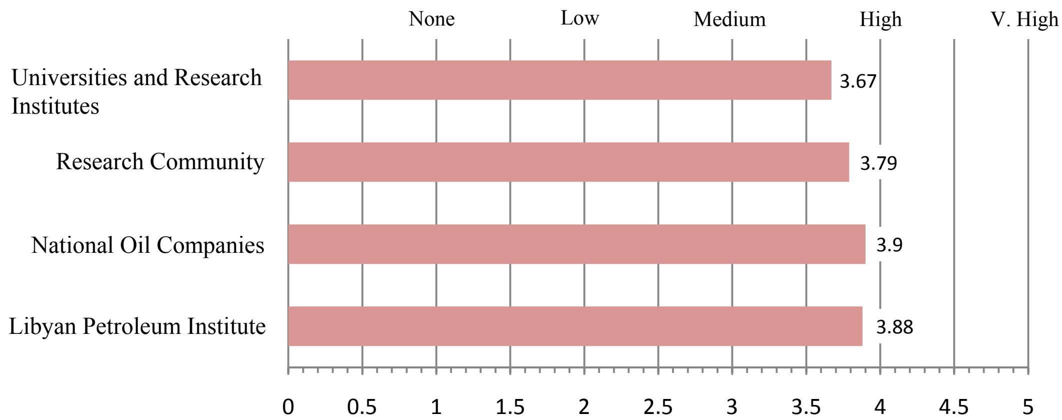


Figure (6.15): Barriers to Successful R&D Projects at Libyan Oil Sector

– *Barriers to Technology Development:* Existence of barriers to developing Libyan petroleum technology has almost strong consensus at LPI (see table 6.21, p.206). Existence of barriers to developing Libyan petroleum technology has clear-cut consensus of both the respondent samples and the populations of national oil companies and research community (see table 6.51 and table 6.69, p.226 & p.238 respectively). Figure 6.16 demonstrates agreement of technological competence domain at Libyan oil sector to existence of barriers of technology development.

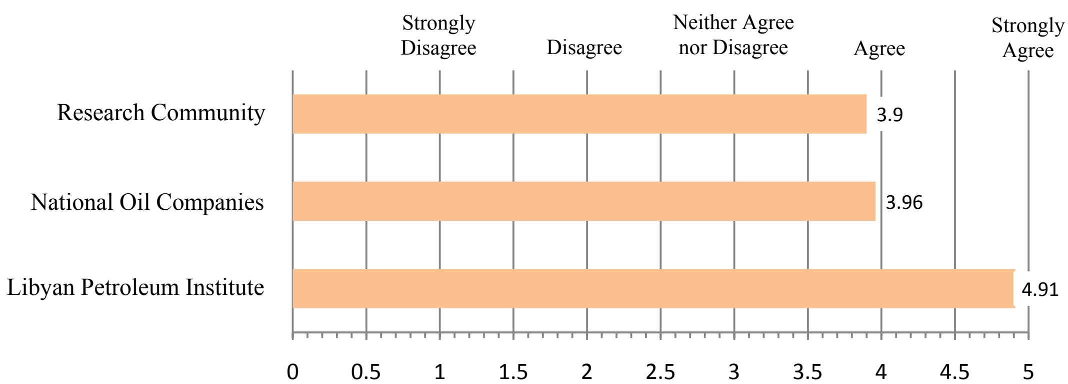


Figure (6.16): Existence of Barriers to Technology Development at Libyan Oil Sector

– *Role of Government towards Technology Development:* The Libyan government support to developing technology is almost rarely watched by LPI and both the respondent sample and the population of national oil companies (see table 6.22 and table 6.52, p.206 & p.226 respectively). Figure 6.17 exhibits role of government towards petroleum technology development in Libyan oil sector.

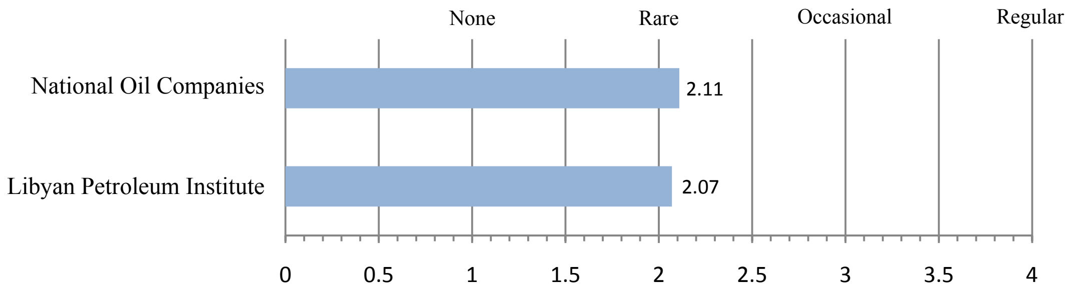


Figure (6.17): Role of Government towards Technology Development in Libyan Oil Sector

– *Scientific and Technological Interactions:* LPI interaction with national oil companies is conducted occasionally and almost conducted occasionally with foreign oil companies. LPI interaction with foreign oil companies is better than with national oil companies. LPI interaction with national universities & research institutes is almost conducted rarely and almost conducted occasionally with foreign universities & research institutes. LPI interaction with foreign universities & research institutes is better than with national universities & research institutes (see table 6.23 and table 6.24, p.207). Figure 6.18 shows various LPI technological interactions.

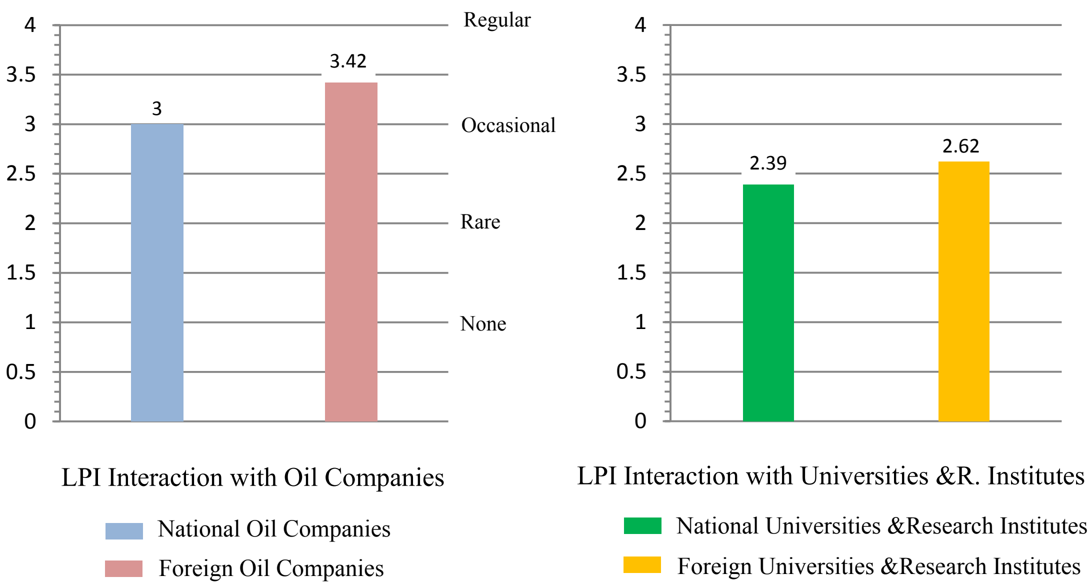


Figure (6.18): Scientific &Technological Interactions of Libyan Petroleum Institute

Interactions of both the respondent sample and the population of national oil companies with LPI and with foreign petroleum research institutes are almost conducted rarely. Interaction with LPI is better than with foreign petroleum research institutes. Interactions of both the respondent sample and the population of national oil companies with national universities & research institutes and with foreign universities & research institutes are almost conducted rarely. Interaction with national universities & research institutes is better than with foreign universities & research institutes (see table 6.53 and table 6.54, pp.227-228). Figure 6.19 shows various technological interactions of national oil companies.

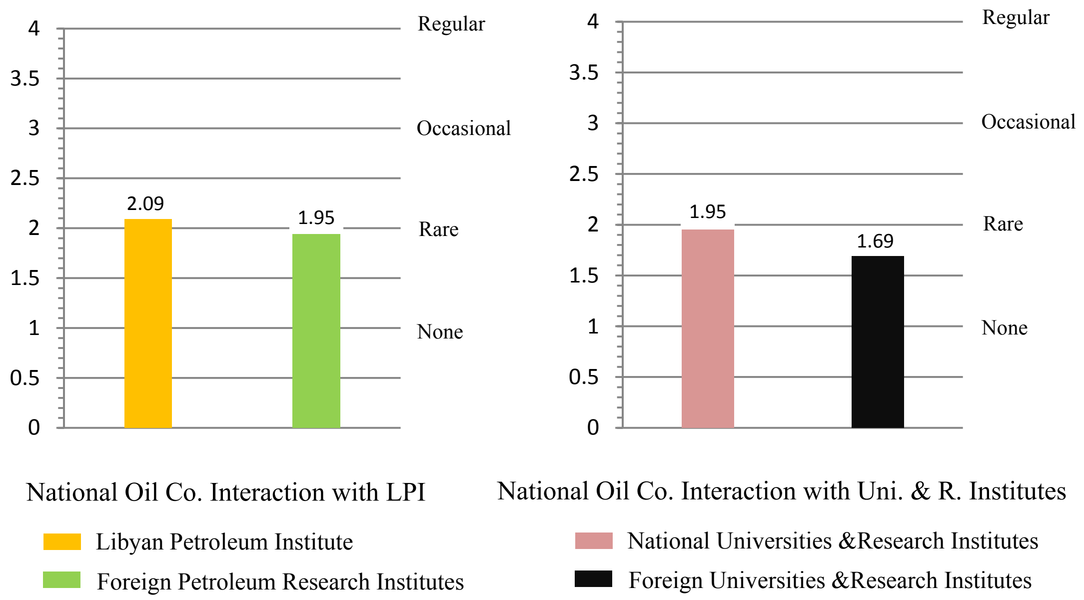


Figure (6.19): Scientific &Technological Interactions of National Oil Companies

– *Structure of Employment:* Structure of R&D personnel at LPI for average of five years encompasses; 24.9% represents researchers, 5.9% for R&D technicians, and 69.2% for supportive staff (see table 6.25, p.208). Distribution of scientific qualifications of LPI's staff for a period of five years is as follows: 13.1% for holders of intermediate diploma, 3.8% for high diploma holders, and 38.2%, which is the largest group, for bachelors. 15.4% for master degree holders, 6.1% for doctorate holders, and 23.4% for professional qualifications (see table 6.26, p.208). Compared to typical distribution of R&D workers in United States of America, for instance in 2003, which has about 59% for bachelors, 28% for masters, 9% for doctorates, and 4% for professional degrees (National Science Board, 2006), the distribution of LPI staff, as being considered mainly R&D personnel, suffers some sort of shortage in bachelors, masters, and doctorates while it has overcapacity in professional qualifications. Figure 6.20 shows structure of R&D workforce and distribution of scientific qualifications at LPI.

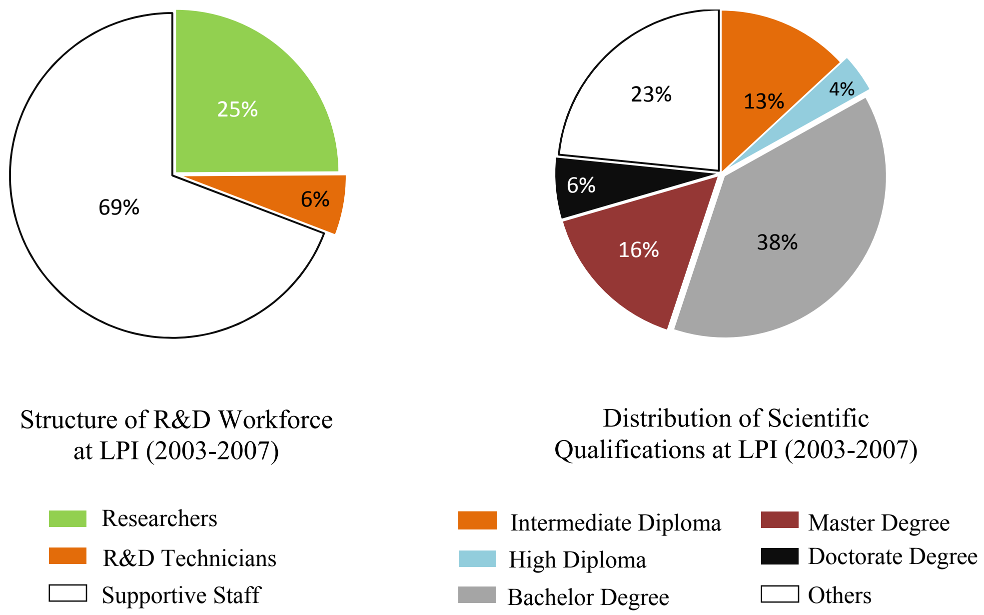


Figure (6.20): Structure of R&D Workforce and Distribution of Scientific Qualifications at LPI

Structure of scientific specialization in LPI indicates that there is an interdisciplinary of basic specialization needed for petroleum R&D with mean values along 2003-2007 as follows: 9.8% for earth scientists (i.e., geologist, geophysicist, and geochemist), 10.2% for petroleum engineers, 6.6% for chemical engineers, 6.9% for chemists, 2% for metallurgist, and 4.4% for other specialization such as physicists, biologists, mechanical engineers, and electrical/electronic engineers (see table 6.27, p.209). Distribution of age versus scientific degree at LPI shows that about 43% of bachelors and 56% of masters are between 35 and 44 years, and about 76% of doctorates are between 45 and 54 years (see table 6.28, p.210). One clear consequence of this age distribution is that a much larger portion of doctorate holders will reach traditional retirement age during the next decade. This alone will have significant effect on supervision of R&D activities if there are no plans to substitute from bachelor and master holders. Figure 6.21 (p.289) reveals the distribution of scientific specialization and distribution of age against scientific degree at LPI.

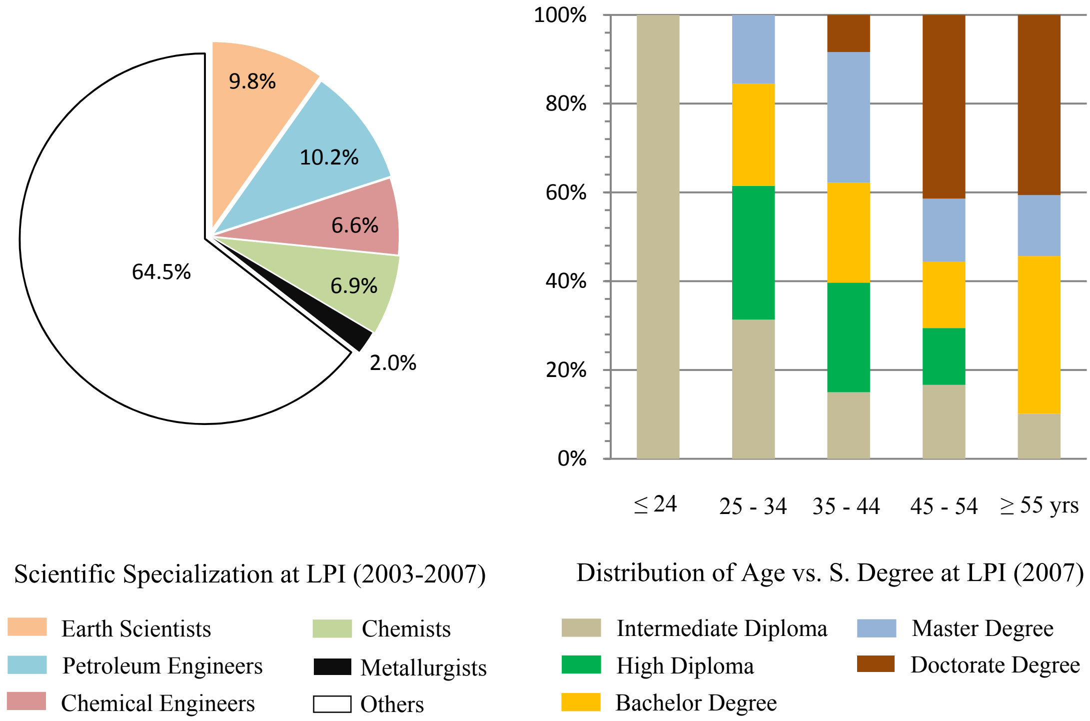


Figure (6.21): Distribution of Specialization and Distribution of Age vs. Scientific Degree at LPI

Gender distribution of technical staff at LPI between 2003 and 2007 is 71% for male and 29% for female (see table 6.29, p.210). The female percentage is comparably consistent with the typical percentage of female, in most science and engineering occupations in United States of America between 1999 and 2003, which is increased from 23% to 27% (National Science Board, 2006).

– *Distribution of Expenditures:* The mean values of expenditures at LPI between 2003 and 2007 are distributed as follows: 31.2% dedicated to R&D activities, 10.2% for material acquisition, 18.6% for technical operations such as various laboratory services and their related studies, 15% for training and development, 8.2% for logistics such as maintenance, catering, transportation, etc., and 16.8% for administration expenses such as salaries, incentive bonuses, etc (see table 6.30, p.210). In addition, there is about 3.4% reduction in percentage of R&D expenditure between 2003 and 2007 at LPI, while there is 100% growth in percentage of training and development expenditure for the same period (see table 6.30). For the Libyan petroleum sector, the total budget has witnessed increase by double between 2003 and 2007 in order to cover the investments in upstream industry with no significant interest to allocate clear-cut budget for sectoral R&D activities (Survey data). Figure 6.22 shows the distribution of expenditures at both LPI and Libyan petroleum sector.

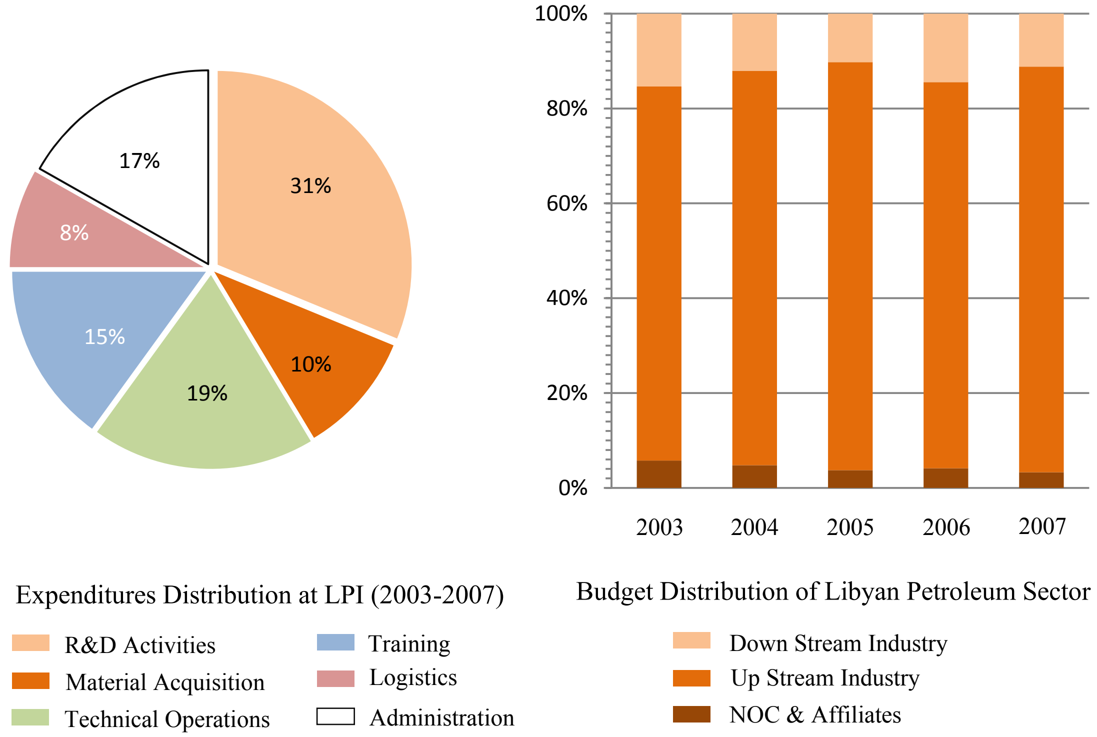


Figure (6.22): Distribution of Expenditures at LPI and Libyan Petroleum Sector

According to the survey data, the mean R&D expenditure at LPI for 2003-2007 is about LD 6.06 Million or 31.2% of mean budget of LPI, and the mean R&D expenditure at national oil companies for the same period is about LD 5.0 Million. The mean total budget of Libyan petroleum sector for 2003-2007 is about LD 2310 Million. Therefore, total R&D expenditure in Libyan petroleum sector is LD 11.06 Million which is equivalent to 0.48% of mean budget of that sector. The size of total R&D expenditure herein indicates that there is no vital role considered for local R&D to play in solving relevant technological problems.

– *Characteristics of Work Environment:* The respondent sample and the population of research personnel are almost neither disagree nor agree about their job satisfaction and the effectiveness of their interpersonal relationships (see table 6.60 and table 6.61, pp.230-231). Job satisfaction and effectiveness of interpersonal relationships at research community is depicted in figure 6.23 (p.291).

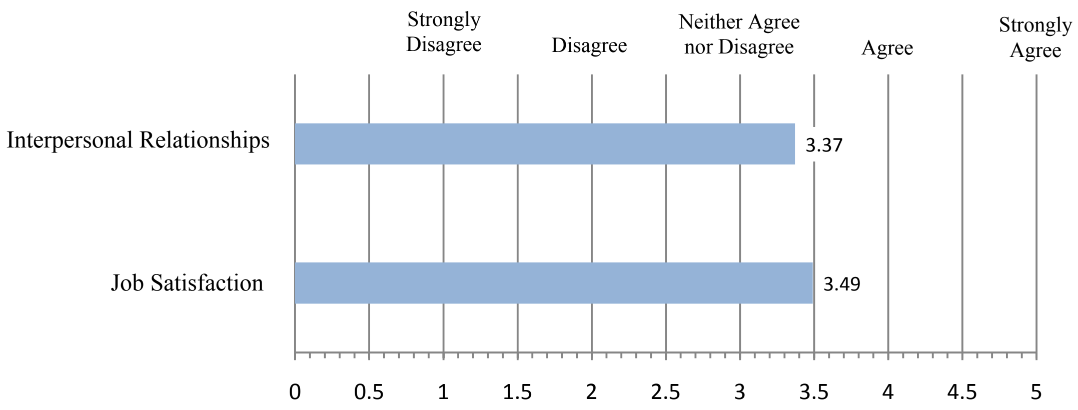


Figure (6.23): Job Satisfaction and Effect of Interpersonal Relationships at Research Community

The respondent sample and the population of research personnel tend to neither disagree nor agree about their accessibility to, and share of, relevant information. They are almost neither disagree nor agree about the effectiveness of information update and they are almost agree about the weakness of information flow through their research community (see table 6.62, p.232). Figure 2.24 shows the status of information and communication process at the research community of Libyan petroleum sector.

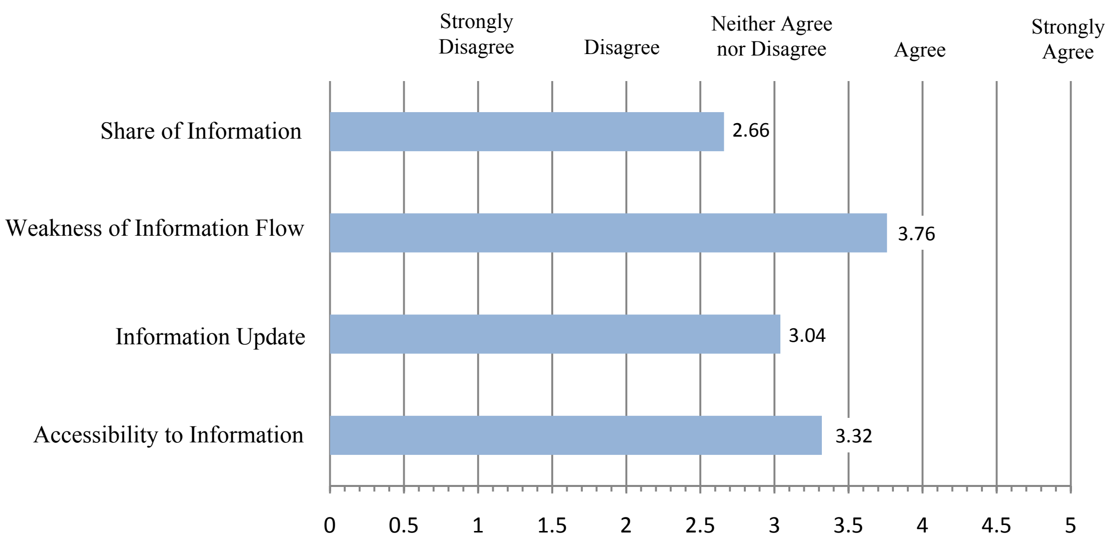


Figure (6.24): Status of Information and Communication Process at Research Community

The respondent sample and the population of research personnel are almost neither disagree nor agree about enhancing the individuals at Libyan public organizations to the organization welfare rather than personnel interests, and they are almost neither disagree nor agree that resistance to change is not big barrier in most of Libyan organizations. The respondent sample and the population of research personnel tend to agree about the widespread belief among most of Libyan organizations that, loyalty before capability when recruiting or assigning work leaders of all levels. Also, they almost agree that time is not much important in daily work life of Libyans. The respondent sample and the population of research personnel are almost neither disagree nor agree that most of Libyan individuals believe that job is worthy to pay much attention as there are real rewarding and promotion systems available. They almost agree that in most of Libyan organizations no real challenging works being seriously considered (see table 6.63, p.234). Figure 2.25 reveals characteristics of organization culture with respect to research community.

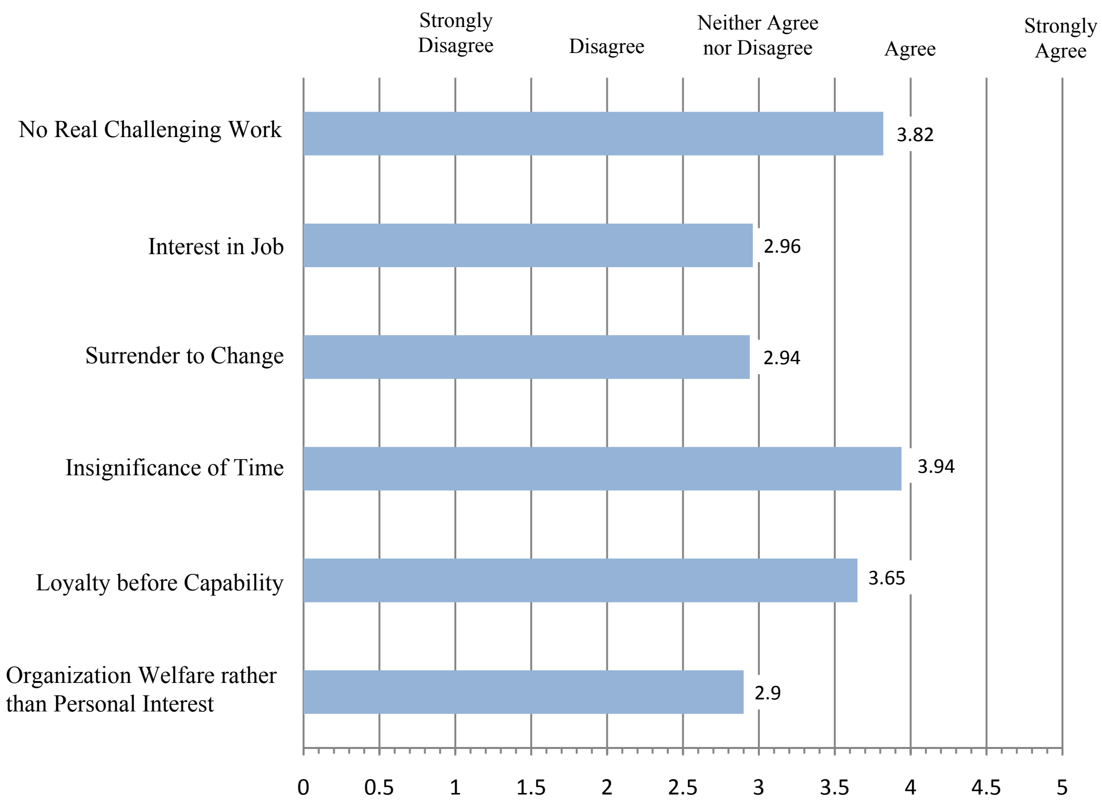


Figure (6.25): Characteristics of Organization Culture at Research Community

The learning climate surrounding the respondent sample and the population of research personnel tends to be at moderate existence degree (see table 6.64, p.235). Status of learning climate at research community is shown in figure 2.26 (p.293).

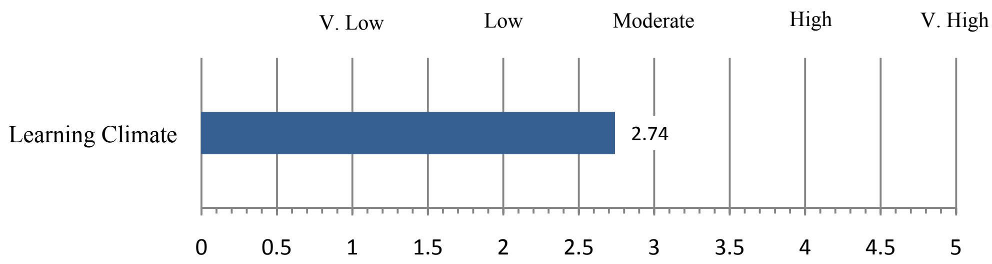


Figure (6.26): Status of Learning Climate at Research Community

For the respondent sample and population of research community, the leader-member relationship is almost good, the conflict of commands tends to be rare, few personnel is almost used to participate in decision making, and the recognition of job description by the employees tends to be done through self-learning manner (see table 6.65, p.236). Effectiveness of managerial system is shown in figure 6.27.

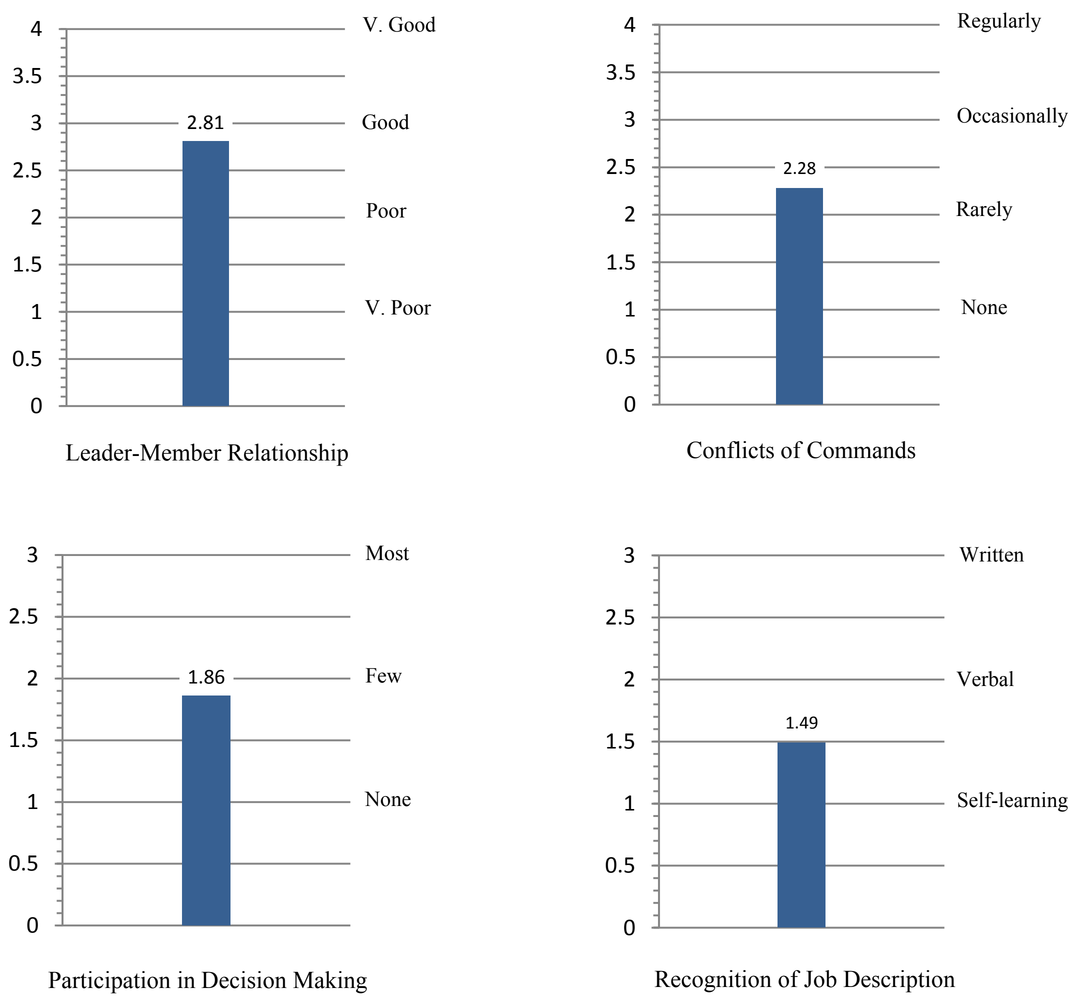


Figure (6.27): Effectiveness of Managerial System at Research Community

– *Characteristics of Team Technological Capabilities:* The team's technological absorptive capacity and conceptualization capability at the respondent sample and the population of research community tend to be at moderate degree (see table 6.66 and table 6.67, p.237). In this sense, the team's technological capability is suffering some weakness and needs to be improved. Figure 6.28 demonstrates characteristics of team technological capabilities.

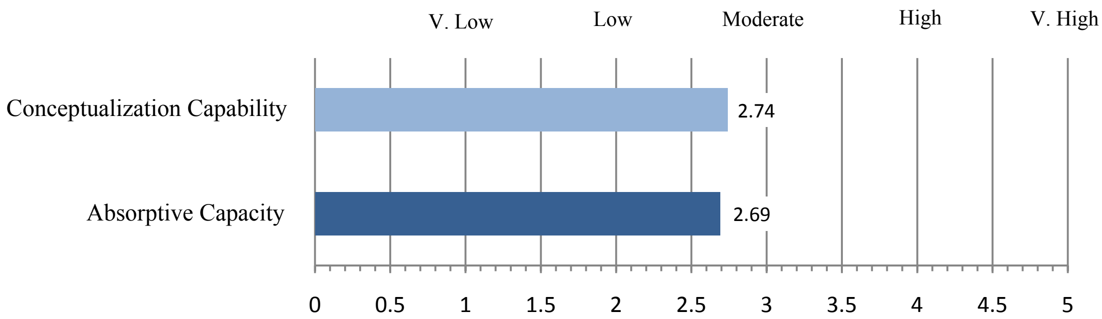


Figure (6.28): Characteristics of Team Technological Capabilities at Research Community

– *Priorities for Technological Change:* More funding for R&D projects, increasing interactions between national oil companies, research institutes and universities are respectively the utmost priorities for technological change in Libyan petroleum sector with respect to the respondent sample of public universities and research institutes. Increasing government institutional support to R&D and more funding for R&D projects are respectively the utmost priorities for technological change with respect to the respondent sample of research community.

Enhancing individual interest in R&D, and formulating effective technology development strategy have respectively the middle attention of the respondent sample of public universities and research institutes. Enhancing individual interest in R&D and formulating effective strategy for technology development have equally the middle attention of the respondent sample of research community for technological change.

Promoting managerial system of Libyan oil industry and motivating native research personnel have respectively less attention of the respondent sample of public universities and research institutes for technological change. Motivating native research personnel and enhancing foreign partnership or collaboration have respectively less attention of the respondent sample of research community for technological change (see table 6.70 and table 6.89, p.239 & p.255 respectively).

Figure 6.29 depicts the priorities for technological change in Libyan petroleum sector with respect to research community, universities and research institutes.

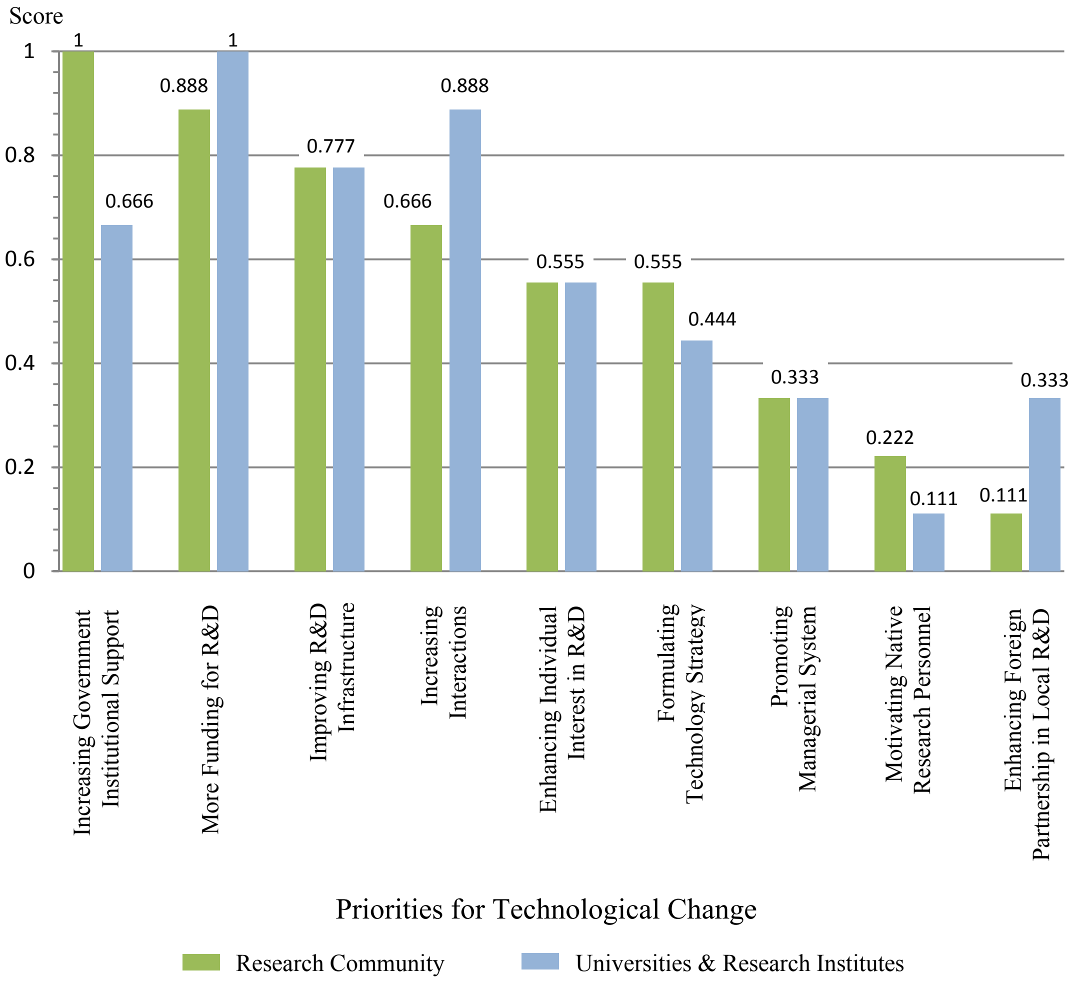


Figure (6.29): Priorities for Technological Change at Libyan Petroleum Sector

– *Foreign Direct Investment (FDI):* The respondent sample of foreign oil companies in Libya is totally involved in petroleum exploration activities. 23.8% is involved in petroleum R&D activities, and probably at less than 41.5% with respect to the population. 66.7% of the respondent sample will involve in petroleum production activities in the future, and probably at less than 80.9% for the population. Only 4.7% of the respondent sample will involve in oil refining activities in the future, and probably at less than 19% with respect to the population. 90.5% of the respondent sample neither is involved nor will be involved in petrochemical manufacturing activities, and probably at less than 96.9% with respect to the population. 81% of the respondent sample neither is involved nor will be involved in technical oil services, and probably at less than 91.2% with respect to the population (see table 6.76, p.244). Figure 6.30 shows type of foreign direct investment in Libyan petroleum sector.

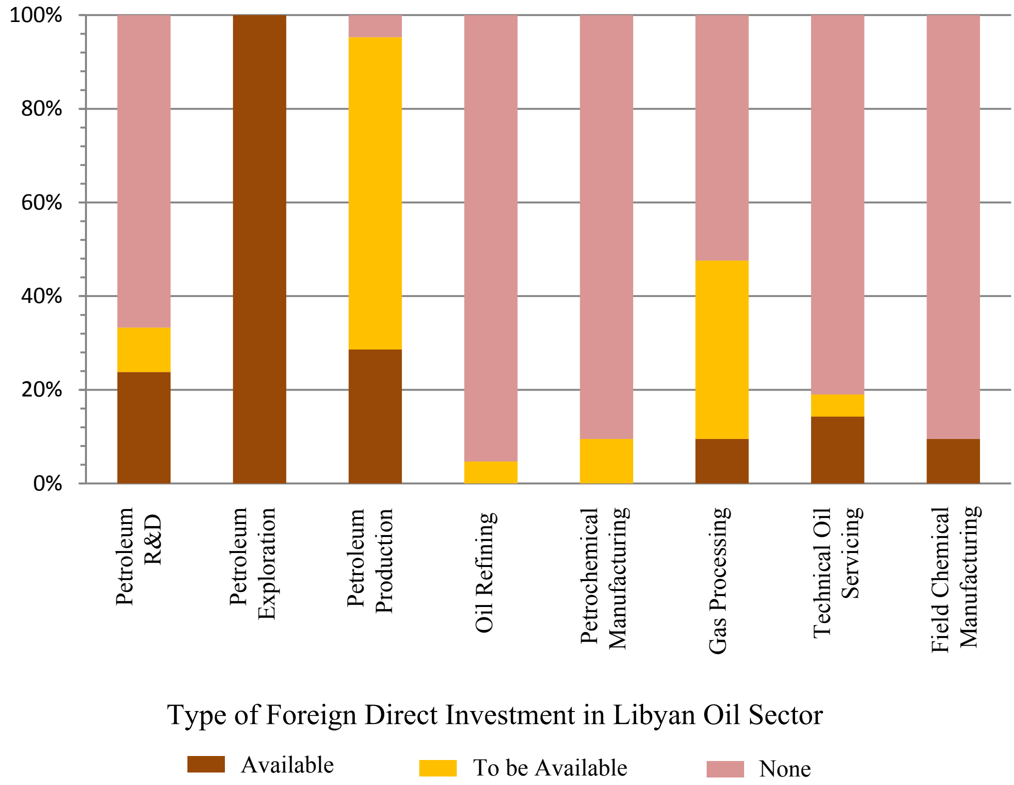


Figure (6.30): Type of FDI in Libyan Oil Sector

The respondent sample of foreign oil companies in Libya is involved by 85.7%in activities of FDI in terms of petroleum production sharing agreement, and probably at less than 94.2% with respect to the population. Only 4.7% of the respondent sample is involved in joint ventures of technical oil servicing, and probably at less than 19% with respect to the population. 28.6% of the respondent sample will involve in acquisition of ready-established oil firms and probably at less than 46.6% with respect to the population. Only 9.5% of the respondent sample will involve in acquisition of ready-established oil laboratories and probably at less than 25.1% with respect to the population. 76.2% of the respondent sample neither is involved nor will be involved in establishing new R&D laboratories, and probably at less than 88.8% with respect to the population (see table 6.77, p.247). Thus, the foreign oil companies in Libya are mainly interested to large extent in petroleum production share agreements and having weak intention in establishing new R&D laboratories. Modes of entry for FDI into Libyan oil sector are shown in figure 6.31.

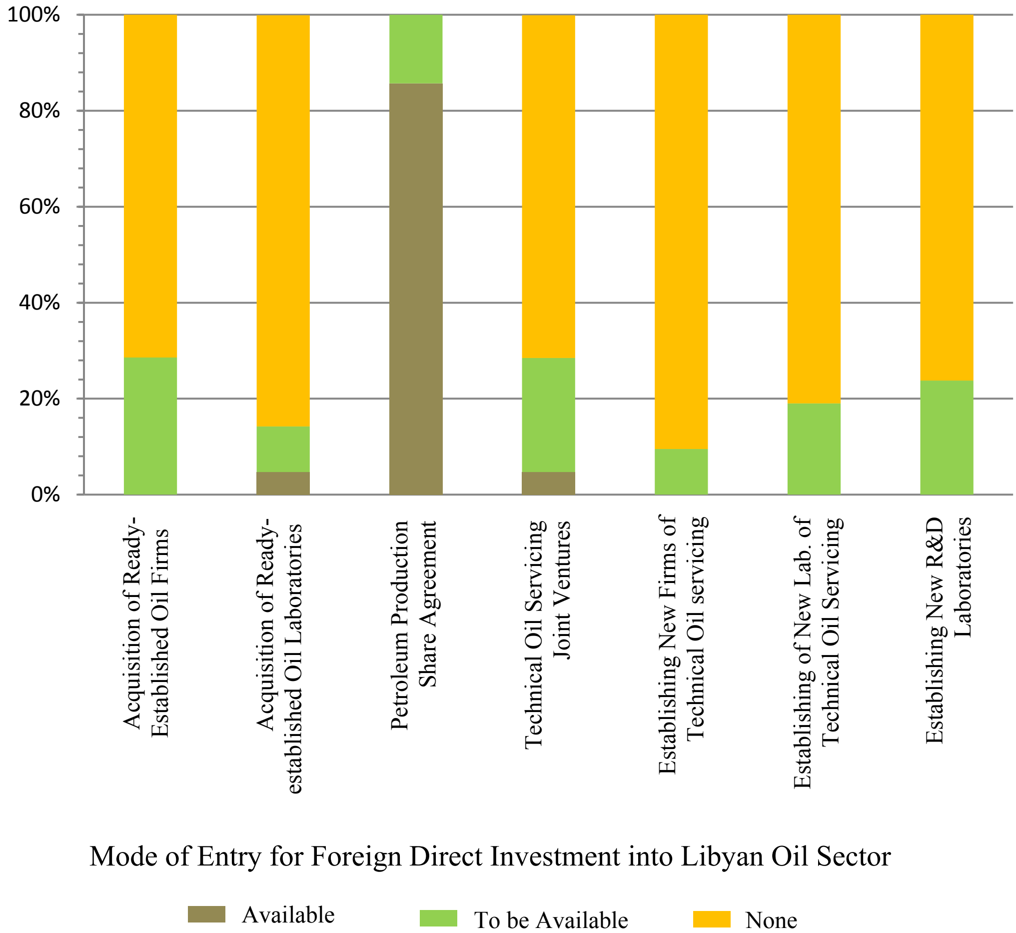


Figure (6.31): Modes of Entry for FDI into Libyan Oil Sector

Existence of barriers to foreign direct investment for technology development in Libya tends to be at medium degree for both the respondent sample and the population of foreign oil companies (see table 6.78, p.248). Figure 6.32 demonstrates degree of existence of barriers to FDI in technology development.

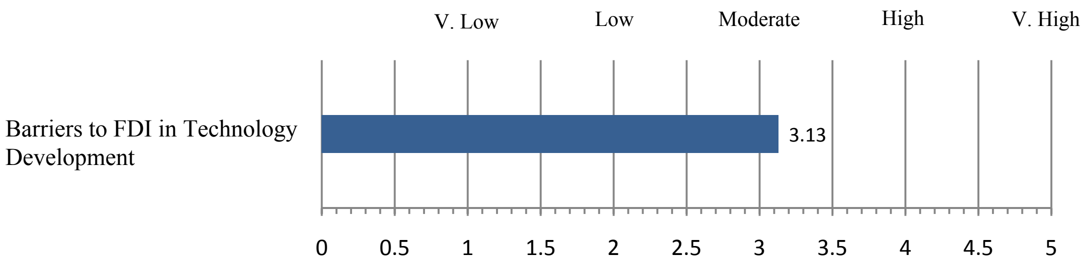


Figure (6.32): Barriers to FDI in Technology Development at Libyan Oil Sector

Building good international reputation, promoting managerial system of Libyan oil industry, and improving indigenous R&D infrastructure are respectively the utmost priorities for encouraging FDI towards technology development in Libyan petroleum sector with respect to the respondent sample of foreign oil companies.

Increasing host government interest & commitment to encourage FDI in R&D, enhancing native individual interest in R&D, and formulating effective sectoral strategy of technology development have respectively the middle attention of the respondent sample for encouraging FDI towards technology development.

Increasing local interactions, motivating foreign direct investment, and strengthening local infrastructure of finance institutions have respectively less attention of the respondent sample for encouraging FDI towards technology development (see table 6.79, p.249). Priorities for encouraging FDI in technology development at Libyan petroleum sector are clearly shown in figure 2.33.

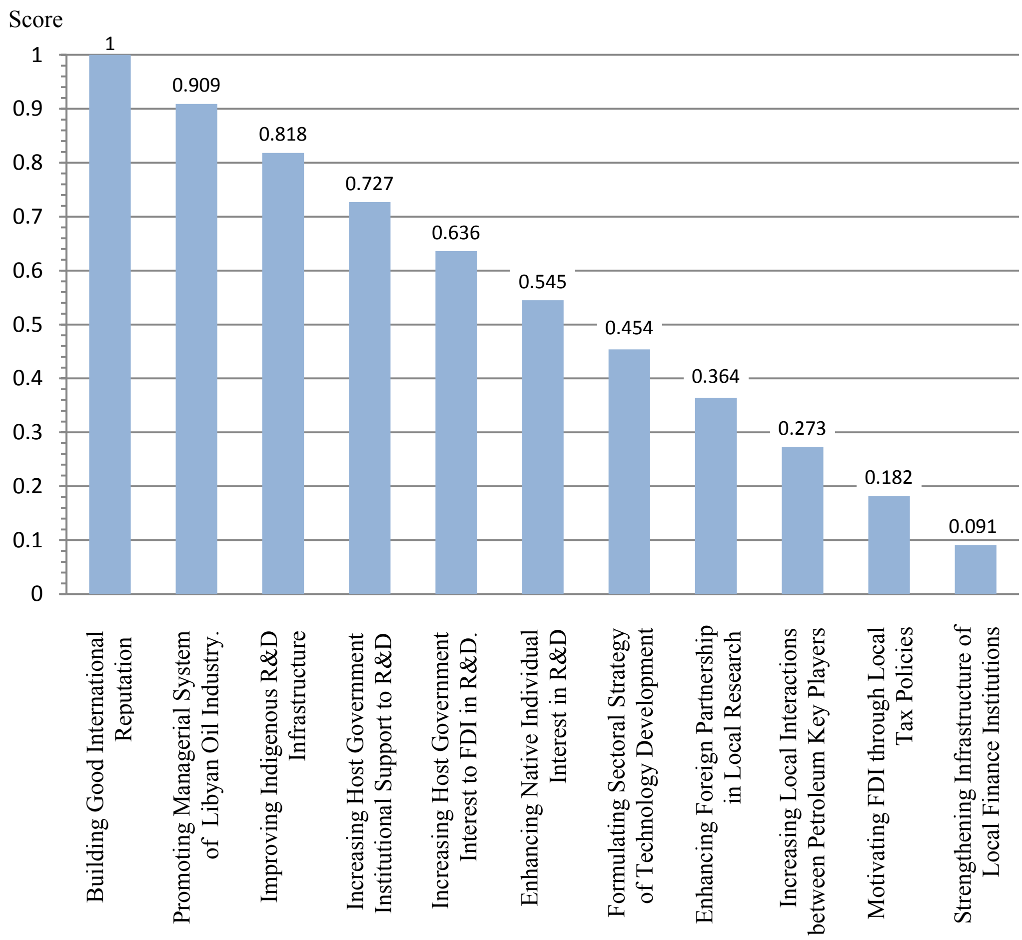


Figure (6.33): Priorities for Encouraging FDI in Technology Development at Libyan Oil Sector

– *Technological Development at Private Sector:* 45.8% of the respondent sample of private companies of technical oil services performs the target activities by their own technical capabilities, and probably at less than 62.2% with respect to the population. 41.6% of the respondent sample is dependent on national collaboration to perform the target activities, and probably at less than 58.2% with respect to the population. 62.5% of the respondent sample is dependent on foreign collaboration to perform the target activities, and probably at less than 76.8% with respect to the population. 25% of the respondent sample does not perform some of the target activities and probably at less than 41.6% with respect to the population (see table 6.96, pp.257-258). Figure 6.34 shows work dependency at private companies of technical oil services.

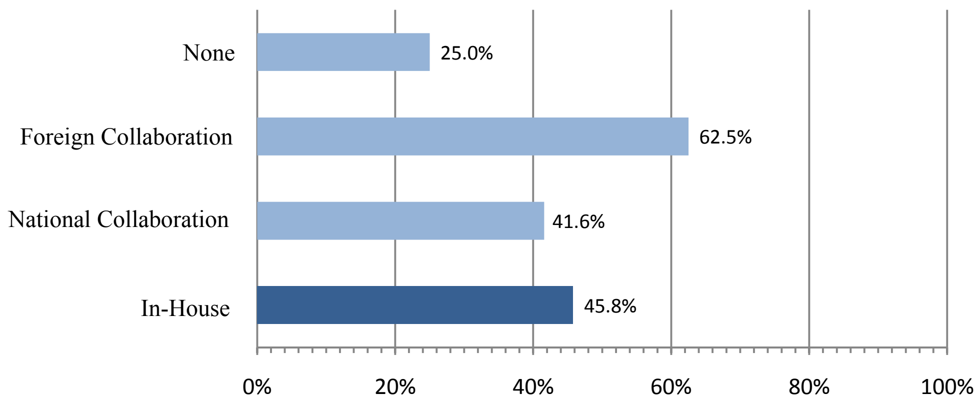


Figure (6.34): Work Dependency at Private Companies of Technical Oil Services

Supporting research activities is almost not existed at both the respondent sample and the population of private services companies (see table 6.98, p.259). Figure 6.35 shows the degree to which supporting the research activities is considered.

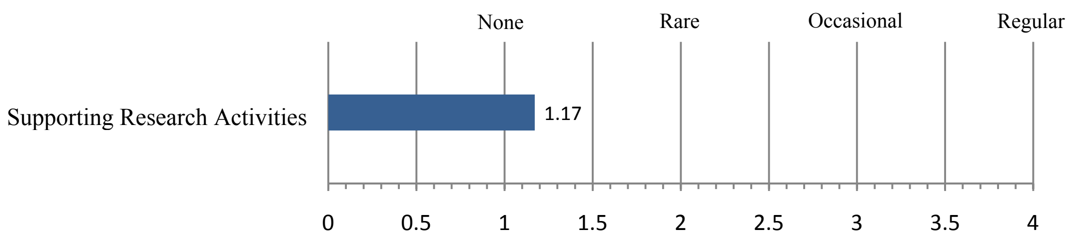


Figure (6.35): Supporting Research Activities at Private Companies of Technical Oil Services

Barriers to supporting technology development in Libya tend to be highly existed at both the respondent sample and the population of private companies of technical oil services (see table 6.99, p.259). Figure 6.36 (p.300) demonstrates the existence of barriers to supporting technology development.

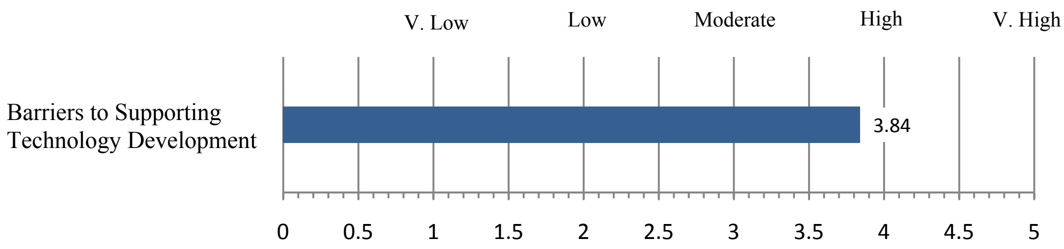


Figure (6.36): Barriers to Supporting Technology Development at Private Sector

Formulating effective strategy for technology development, and improving national R&D infrastructure, and offering opportunities for private firms to expand profits are respectively the utmost priorities for supporting R&D with respect to the respondent sample of private companies of technical oil services.

Increasing government interest & commitment to encourage R&D, promoting managerial system of Libyan oil industry, and increasing local interactions have respectively the middle attention of the respondent sample of these companies.

Increasing government institutional support to in-house R&D and building good international reputation have respectively less attention of the respondent sample (see table 6.100, p.260). Figure 6.37 illustrates priorities toward supporting R&D at private companies of technical oil services.

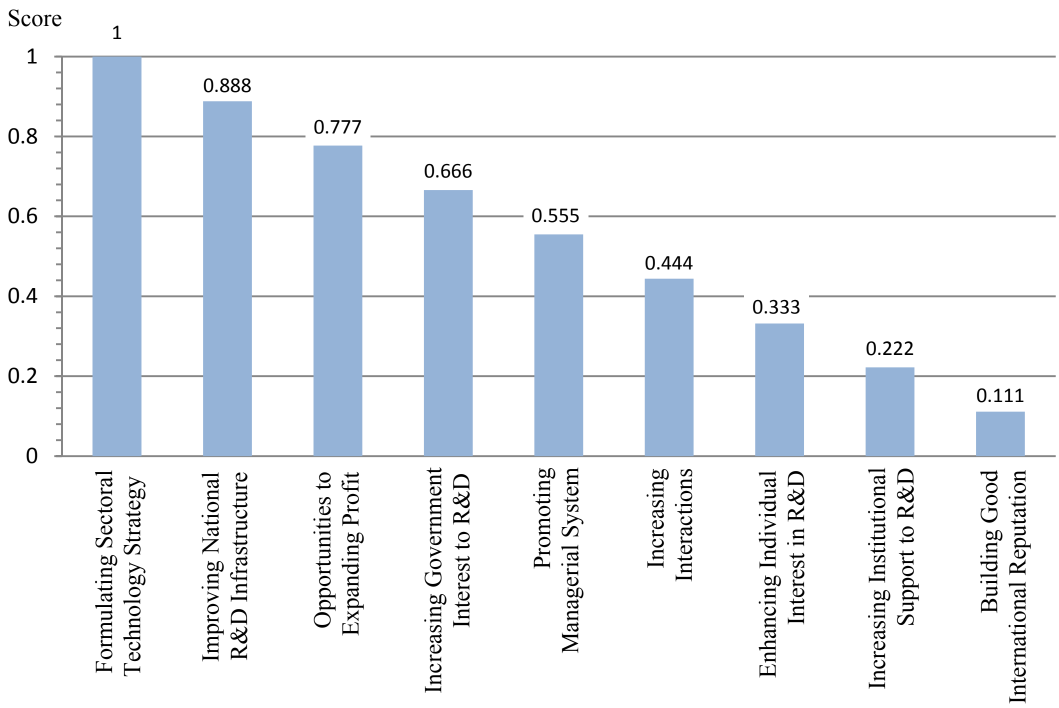
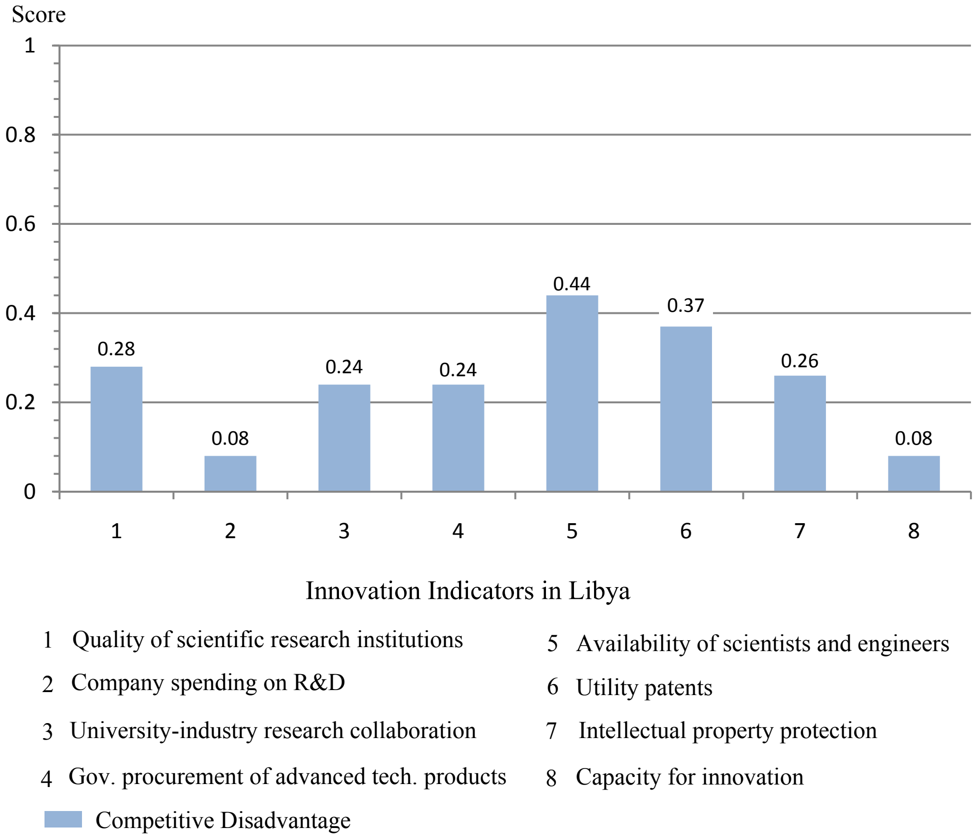


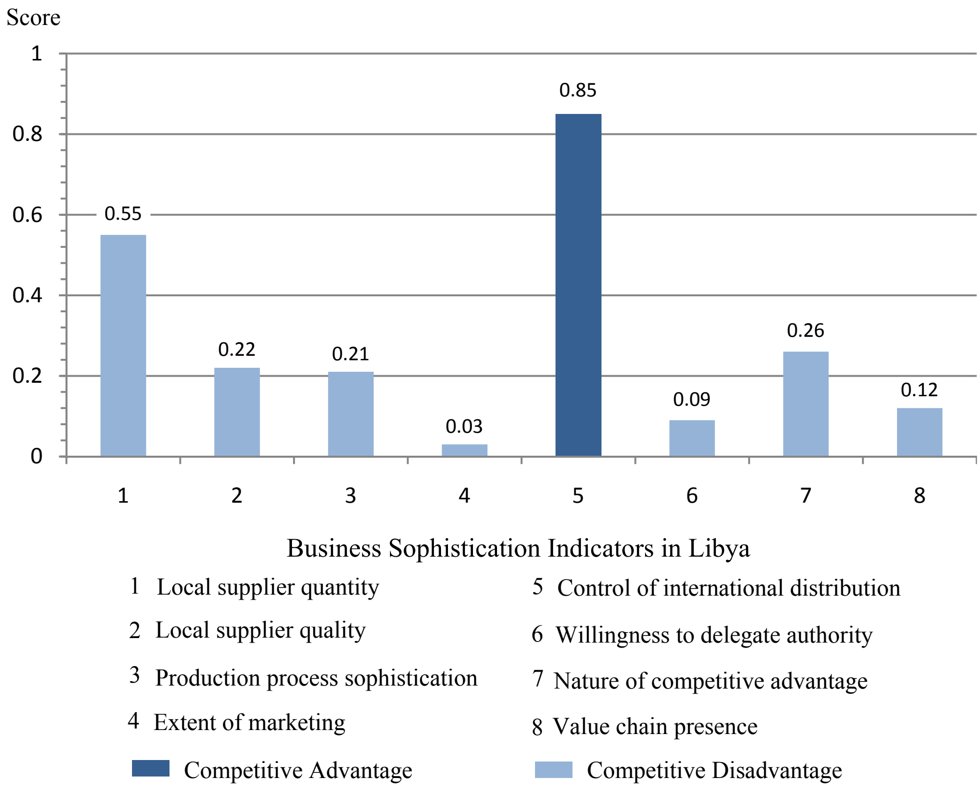
Figure (6.37): Priorities toward Supporting R&D at Private Sector

– *Libya Technological Competitiveness:* In accordance with the global competitiveness report 2007, published by World Economic Forum, which ranks 128 countries worldwide according to their competitiveness indices, Libya scores 3.2 out of 7.0 points in innovation factors. These factors include eight innovation indicators which score 2.8, and eight business sophistication indicators which score 3.6. The eight innovation indicators are as follows: 1) Quality of scientific research institutions. 2) Company spending on R&D. 3) University-industry research collaboration. 4) Government procurement of advanced technological product. 5) Availability of scientists and engineers. 6) Utility patents. 7) Intellectual property protection. 8) Capacity for innovation. In addition, the eight business sophistication indicators comprise: 1) Local supplier quantity. 2) Local supplier quality. 3) Production process sophistication. 4) Extent of marketing. 5) Control of international distribution. 6) Willingness to delegate authority. 7) Nature of competitive advantage. 8) Value chain presence. The details of these indicators are shown in figures 6.38 and figure 6.39 (p.302).



Source: Adapted from World Economic Forum (2007)

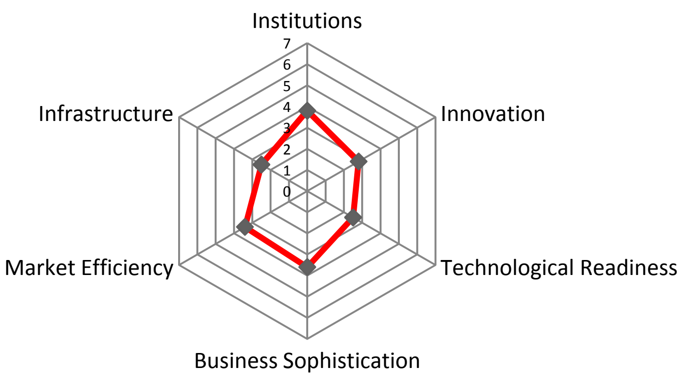
Figure (6.38): Libya Innovation Indicators in 2007



Source: Adapted from World Economic Forum (2007)

Figure (6.39): Libya Business Sophistication Indicators in 2007

Moreover, in some other related competitiveness factors which are crucial along with the previous ones to the process of catch-up capacity building (see UNIDO, 2005), Libya scores are as follows: I) The basic requirements factors including institutions index 3.8 out of 7 points, and infrastructure index 2.5. II) The efficiency enhancers such as market efficiency index 3.4, and technology readiness 2.5 (WEF, 2007). Figure 6.40 depicts some competitiveness scores of Libya in 2007.



Source: Adapted from World Economic Forum (2007)

Figure (6.40): Libya Competitiveness Indicators in 2007

6.5.2 Areas of Concern

In accordance with all research findings demonstrated earlier, one can conclude accordingly some areas of concern that should be considered towards successful technology development within the postulate management framework. Table 6.109 summarizes these deductive key areas of concern.

NO.	CRITERIA & STATUS	AREA OF CONCERN
1	*Criterion*: INVOLVEMENT IN R&D *Status*: – Involvement of LPI, national oil companies, public universities and research institutes, and private companies of technical oil services in R&D is almost weak.	– Organization involvement in R&D – Individual interest in R&D – Sectoral R&D strategy – Organizational R&D Strategy
2	*Criterion*: R&D PRIORITIES *Status*: – There is a sort of vision diversion between LPI and national oil companies towards R&D output, where the former looks for strategic technological vision and the latter has an operation-oriented vision. As such, R&D collaboration between both sides might not lead to well-coordinated approach due to existence of different visions. – Competition purpose comes at the ninth priority, for both LPI and national oil companies, which indicates that both players are not working under high competition circumstances that entail high involvement in R&D activities to challenge rivals.	– Sectoral R&D strategy – Organizational R&D Strategy – Significance of developing technology in support of national economy
3	*Criterion*: R&D DEPENDENCY *Status*: – LPI and national oil companies are both dependent to good extent on their technical capabilities in performing R&D.	– Individual interest in R&D – Native R&D skills
4	*Criterion*: GENERATING R&D IDEAS *Status*: – LPI depends largely on internal and external involvement in generating R&D ideas rather than involvement of government. National oil companies show very low interest in generating R&D ideas.	– Organizational R&D strategy – Sectoral R&D strategy – Technological opportunities – Role of government in developing technology

		– Conceptualization capability of team
5	*Criterion*: MODELLING TECHNOLOGY DEVELOPMENT *Status*: – The interactive model that combines both the science - technology push and market pull is the regular pattern used in technology development endeavours in LPI. Modelling technology development is almost rarely performed at national oil companies. This indicates that there is no vital interest in technology development at national oil companies based on deliberate modelling.	– Organizational learning – Education & training schemes
6	*Criterion*: STRUCTURE OF R&D FACILITIES *Status*: – LPI is very well-equipped with R&D physical facilities than national oil companies have. Both key players suffer shortage of R&D intellectual facilities to different degrees.	– Local R&D infrastructure – R&D collaboration – Local R&D performance
7	*Criterion*: SCIENTIFIC & TECHNICAL OUTPUT *Status*: – LPI and national oil companies focus mainly on elements of knowledge accumulation (i.e., researcher papers, scientific articles, technical studies, technical performance reports, and electronic publications) rather than producing technology (i.e., technical know-how, applied patents, granted patents). – LPI has more regular scientific and technical output than national oil companies do. Scientific and technical output of national oil companies is almost rare. Both LPI and national oil companies has no interest in producing about half of presumed technical and scientific output. – LPI and national oil companies have weak scientific and technical output.	– Capacity for scientific & technical output – Technology institutional framework – Organization international outlook
8	*Criterion*: COMPETENCY FOR TECHNOLOGICAL ASSIMILATION *Status*: – Competency of LPI to assimilate utilized technology is almost twofold competency of national oil companies. – Overall technology assimilation at technological competence domain of Libyan oil sector is almost	– Assimilation of inward technology transfer – Technological absorptive capacity of team – Education &training schemes – Catching-up environment

	good.	
9	*Criterion*: INWARD TECHNOLOGY TRANSFER *Status*: – LPI is more open to inward technology transfer than national oil companies do, and overall technology transfer to technological competence domain of Libyan oil sector has an occasional rate.	– Support of inward technology transfer – Innovation culture – Role of Innovative firms – Catching-up environment
10	*Criterion*: DEPENDENCY ON FOREIGN SUPPLIER *Status*: – Dependency on foreign supplier to meet the technological needs of competence domain of Libyan oil sector is almost high.	– Involvement of native technology supplier
11	*Criterion*: CHARACTERISTICS OF TRAINING & DEVELOPMENT *Status*: – Training and development programmes at technological competence domain of Libyan oil sector are conducted to large extent by foreign collaboration, while national collaboration and in house capabilities have weak existence.	– Education & training by natives – Assimilation of inward technology transfer
12	*Criterion*: SIGNIFICANCE OF TECHNOLOGY DEVELOPMENT *Status*: – Significance of technology development to survival in LPI is at low consideration. LPI is used to formulate its own technology strategy and get involved in efforts of petroleum technology development. LPI has not felt any government commitment or support to set a national or sectoral S&T strategy. LPI has not received any kind of local or international fund for developing technology. – Significance of technology development to survival has a medium-level of consideration at national oil companies. Some of national oil companies are used to formulate their own technology strategy. Some of them are involved in efforts of petroleum technology development. National oil companies have not felt any government support to set a national or sectoral S&T strategy. Small part of national oil companies has received some kind of fund for petroleum technology development. – Hence, technology development is not much significant	– Significance of developing technology in support of national economy – technology institutional framework – Role of government in developing technology – Sectoral technology strategy – Organizational technology strategy – Innovation culture – Inward FDI for technology development

<table>
<tr><td></td><td>to technological competence domain of Libyan oil sector.</td><td></td></tr>
<tr><td>13</td><td>Criterion: BARRIERS TO SUCCESSFUL R&D PROJECTS
Status:
– Barriers to successful R&D projects are almost existed to high extent at LPI, national oil companies, and research community. Barriers to successful R&D projects tend to be existed to high extent at public universities and research institutes.
– Thus, successful R&D projects face barriers to high degree at Libyan oil sector.</td><td>– Native R&D skills
– Individual interest in R&D
– Top management commitment to R&D
– Technological interactions
– Management of resources
– Organizational R&D strategy
– Fund of local R&D
– Technology institutional framework
– Foreign R&D partnership
– Local R&D infrastructure
– Local R&D performance</td></tr>
<tr><td>14</td><td>Criterion: BARRIERS TO TECHNOLOGY DEVELOPMENT
Status:
– Existence of barriers to developing petroleum technology has almost strong consensus at LPI and has clear-cut consensus of both national oil companies and research community.</td><td>– Top management commitment to developing technology
– Performance of sectoral innovation system
– Technology institutional framework
– Innovation culture
– Sectoral technology strategy
– Local R&D infrastructure
– Role of innovative firms
– Catching-up environment
– Technological interactions
– Inward FDI for technology development
– Innovation initiatives
– Technological entrepreneurship</td></tr>
<tr><td>15</td><td>Criterion: ROLE OF GOVERNMENT TOWARDS TECHNOLOGY DEVELOPMENT
Status:</td><td>– Technology institutional framework
– Sectoral technology strategy</td></tr>
</table>

	– The Government support to developing Libyan petroleum technology is almost rarely watched by LPI and national oil companies.	– Performance of sectoral innovation system – Significance of developing technology in support of national economy – Local R&D infrastructure – Technological interactions – Inward FDI for technology development – Innovation initiatives – Technological entrepreneurship – Innovation culture – Local innovation performance – Skills supply
16	*Criterion*: SCIENTIFIC & TECHNOLOGICAL INTERACTIONS *Status*: – LPI interaction with oil companies is almost occasionally. LPI interaction with foreign oil companies is better than with national oil companies. LPI interaction with national universities & research institutes is almost rarely and almost occasionally with foreign universities & research institutes. – Interactions of national oil companies with LPI and with foreign petroleum research institutes are almost rarely. Interaction with LPI is better than with foreign petroleum research institutes. Interactions of national oil companies with universities & research institutes are almost rarely. Interaction with national universities & research institutes is better than with foreign universities & research institutes.	– Technological Interactions – R&D collaboration – Organization international outlook
17	*Criterion*: STRUCTURE OF EMPLOYMENT *Status*: – Distribution of LPI staff, as being represented the research community in Libyan oil sector, suffers some sort of shortage in bachelors, masters, and doctorates while it has overcapacity in professional qualifications. – Distribution of age versus scientific degree at LPI shows that a large part of doctorate holders will reach traditional retirement age during the next decade. This	– Management of resources – Education & training schemes – Organizational learning – Skills supply – Catching-up environment

	alone will have significant effect on supervision of R&D activities if there are no plans to create substitutes from bachelor and master holders. – Gender distribution of technical staff of LPI is comparably consistent with sex distribution in science and engineering occupations worldwide.	
18	*Criterion*: DISTRIBUTION OF EXPENDITURES *Status*: – The total budget of Libyan oil sector has witnessed increase by double between 2003 and 2007 in order to cover the size of investments in upstream industry with no significant interest to allocate clear-cut budget for sectoral R&D activities. – The size of R&D expenditure in Libyan oil sector is very modest. This indicates that there is no vital role has been considered for local R&D to play in solving relevant technological problems.	– Management of resources – Fund of local R&D – Significance of developing technology in support of national economy
19	*Criterion*: CHARACTERISTICS OF WORK ENVIRONMENT *Status*: – The research personnel are almost neither disagree nor agree about their job satisfaction and the effectiveness of their interpersonal relationships. – The research personnel tend to neither disagree nor agree about their accessibility to, and share of, relevant information. They are almost neither disagree nor agree about the effectiveness of information update and they are almost agree about the weakness of information flow through their research community. – The research personnel are almost neither disagree nor agree about enhancing the individuals at Libyan public organizations to the organization welfare rather than personnel interests, and they are almost neither disagree nor agree that resistance to change is not big barrier in most of Libyan organizations. The research personnel tend to agree about the widespread belief among most of Libyan organizations that, loyalty before capability when recruiting or assigning work leaders of all levels. Also, they almost agree that time is not much important in daily work life of Libyans. The research personnel are almost neither disagree nor agree that most of Libyan individuals believe that job is worthy to pay much attention as there are real rewarding and promotion systems available. They almost agree that in	– Job satisfaction and interpersonal relationship – Information and communication process – Positive organizational culture – Organizational learning – management system

	most of Libyan organizations no real challenging works being seriously considered. – The learning climate surrounding the research community tends to be at moderate existence degree. – At research community, the leader-member relationship is almost good, the conflict of commands tends to be rare, almost few personnel is used to participate in decision making, and the recognition of job description by the employees tends to be done through self-learning manner.	
20	*Criterion*: CHARACTERISTICS OF TEAM TECHNOLOGICAL CAPABILITIES *Status*: – At the research community, the team's technological absorptive capacity and conceptualization capability tend to be at moderate degree. In this sense, the team's technological capability is suffering some weakness and needs to be improved.	– Technological absorptive capacity of team – Conceptualization capability of team – Education & training schemes – Catching-up environment
21	*Criterion*: PRIORITIES FOR TECHNOLOGICAL CHANGE *Status*: – With respect to research community and public universities & research institutes, increasing institutional support to R&D, more funding for R&D activities, increasing interactions between key players of Libyan petroleum sector, and improving R&D infrastructure are respectively the utmost priorities for technological change in Libyan oil sector.	– Technology institutional framework – Fund of local R&D – Technological interactions – Local R&D infrastructure
22	*Criterion*: FOREIGN DIRECT INVESTMENT *Status*: – The foreign oil companies in Libya are totally involved in petroleum exploration activities, with less attention to other petroleum activities including downstream industry and R&D. – The foreign oil companies in Libya are mainly involved to large extent in petroleum production sharing agreements, and having weak intention to establishing new R&D laboratories in Libya. – Existence of barriers to FDI in Libya for petroleum technology development tends to be at medium degree. – With respect to foreign oil companies, building good international reputation for local research	– Organization international outlook – Management system – Local R&D infrastructure

	organizations, promoting managerial system of Libyan oil industry, and improving national R&D infrastructure are respectively the utmost priorities for encouraging inward FDI in developing technology in Libyan petroleum sector.	
23	*Criterion*: TECHNOLOGICAL DEVELOPMENT AT PRIVATE SECTOR *Status*: – The private companies of technical oil servicing in Libya are dependent to large degree on foreign collaboration to perform their target work. – Supporting research activities is almost not existed at private companies of technical oil services. – Barriers to supporting petroleum technology development in Libya tend to be highly existed at private companies of technical oil services. – With respect to private companies of technical oil services, formulating effective sectoral technology strategy, improving national R&D infrastructure, and offering opportunities for private companies to expand profits are respectively the utmost priorities for supporting R&D.	– Role of private business sector – Innovation culture – Native R&D skills – Individual interest in R&D – Top management commitment to R&D – Technological interactions – Technology institutional framework – Local R&D infrastructure – Local R&D performance – Sectoral technology strategy
24	*Criterion*: LIBYA TECH. COMPETITIVNESS *Status*: – Libya almost has no competitive advantages in innovation, and business sophistication. – The only competitive advantage that Libya has in business sophistication is the control of international distribution. – For the quality of institutions, Libya is located at the transition stage of development; from factor-driven economies to efficiency-driven economies (see World Economic Forum, 2007). – For the quality of infrastructure, market efficiency, technological readiness, business sophistication, and innovation; Libya is located at the stage of factor-driven economies which is the lowest development stage.	– Role of government in developing technology – Top management commitment to R&D – Performance of national/sectoral innovation system – Local R&D infrastructure – Innovation initiatives – Technological interactions – Technological entrepreneurship – Catching-up environment – Innovation culture – Local innovation performance

Table (6.108): Deductive Key Areas of Concern

6.5.3 Reasoning the Phenomenon

The results of investigation made to study the phenomenon under consideration (i.e., the petroleum technology in Libya is not developed successfully) reveal some remarkable conclusions of interest. Poor competence of Libyan oil sector for technological development leads mainly to reasoning this phenomenon as a result of some essential causes, namely:

– Weak drivers to petroleum technology development in Libya owing to: 1) Very poor funding for R&D activities. 2) Low significance of technology development for national economy at petroleum organizations and government level. 3) Weak role of Libyan Government towards petroleum technology development. 4) Rare scientific and technological interactions between the technological key players in Libyan oil industry.

– Weak enablers of petroleum technology development in Libya due to: 1) Poor involvement of Libyan oil industry in R&D activities. 2) Weak self-dependence in doing R&D activities. 3) No vital interest in developing technology based on deliberate modelling. 4) Weak competency of native technical teams to assimilate the technologies being utilized along various petroleum operations. 5) Occasional rate of inward technology transfer that reflects degree of openness of Libyan oil sector to global technology. 6) Very weak self-dependence of Libyan oil sector in doing training and development schemes. 7) Feeble absorptive capacity of research community to acquire, absorb and develop technological knowledge. 8) Narrow conceptualization capability of research community to build shared vision, formulate technology strategy and explore at the end of the day possible technological opportunities. 9) Unseemly learning climate towards developing technology. 10) Low effectiveness level of managerial system at research community. 11) Poor self-dependence of technical oil services companies in private sector to execute their own work.

– Poor scientific and technical output of Libyan oil sector in terms of rate of producing research papers and articles, technical bulletins, technical standards, technical directives, scientific books, technical performance reports, applied and granted technological patents, technical copyrights and trademarks, rate of issuing technological know-how licences, and rate of performing technical consultations and industrial designs.

– Strong influence of barriers to technology development at Libyan oil sector as a consequence of impact of the following factors: 1) High barriers to successful R&D projects and technology development at technological competence domain. 2) Temperate barriers to inward FDI in favour of developing technologies.3) High barriers at private companies of technical oil services to support action plans of technology development. 4) Effect of globalization on sectoral efforts for technological acquisition in terms of high dependence on foreign technology supplier which in turn reduces the chance for native suppliers to innovate and create sustainable competitive advantages. 5) Sensible influence of organization culture spread at the research community against some valuable principles by which the productivity of personnel can be enhanced.

Chapter Seven

MANAGEMENT FRAMEWORK FOR TECHNOLOGY DEVELOPMENT (MFTD)

7. MANAGEMENT FRAMEWORK FOR TECHNOLOGY DEVELOPMENT (MFTD)

7.1 INTRODUCTION

The management framework for technology development (MFTD) described in this chapter is developed in order to help building catching-up capacity and establishing an appropriate business environment for technology development, in Libyan oil sector particularly, or in any similar sector of developing country. This framework is evolutionary and should be subject to reconsideration as our knowledge about determinants of innovation processes increases every so often.

The MFTD is actually the research overall outcome which was originated by developing an empirical understanding of technology development implications in Libyan oil sector, and through exploring the experiential stock of research organizations, firms and business sectors involved in technological innovation in both industrialized and developing countries.

This framework is built based on the idea that: Traditional frameworks of innovation system such as national innovation system (NIS) and sectoral innovation system (SIS) focus to a large extent on analyzing the innovation systems at the macro-level of developed countries in order to maintain or improve an already established level of competitiveness and growth. These traditional frameworks are not sufficient alone to address problems of knowledge generation and producing technology in developing countries. The specific nature of the innovation systems and its related issues, such as catching-up concern, low competitiveness level etc., in developing countries is different from the developed counterparts. Hence, this framework originated to introduce a different guidance to technology development at both macro-level and micro-level of developing countries.

This chapter is structured to demonstrate in the subsequent section the types and sources of activities that constitute the technology management framework. Throughout the remaining sections all these activities, which will assist the Libyan oil sector building its technological catching-up capacity, will be detailed.

7.2 ACTIVITIES OF THE FRAMEWORK

The MFTD is an explanatory framework designed essentially on activity-based approach to include three interrelated types of management activities; planning activities, action activities and controlling activities in accordance with the fundamentals of management discipline.

The research findings as demonstrated in section 6.5 (pp.274-312) have led to identify strengths and weaknesses of the technological competence of Libyan oil industry. The identification of weaknesses in turn has revealed some areas of concern that should be considered towards developing successful petroleum technologies in Libya (see table 6.108, pp.303-310). These areas of concern in Libyan oil sector are urging accordingly to achieve the following corrective activities within the management framework of technology management:

- *Planning Activities*: This includes a set of activities that aim to targeting strategic technological opportunities. The planning consideration in this regard comes as a result of increasing concern about; significance of technology strategy at Libyan oil industry, role of Libyan government in technology development, top management commitment towards developing technology, significance of developing technology in support of national economy, and determining technological opportunities for oil organizations. Targeting strategic technological opportunities can be accordingly accomplished by formulating technology strategy at sector and organization levels of Libyan oil industry.

- *Action Activities*: This comprises some action activities that aim essentially at: 1) *Generating technological knowledge* which is arisen due to influence of concerns about; individual interest and organization involvement in R&D at Libyan oil sector, native R&D skills and skills supply, local R&D infrastructure, capacity of organizations for scientific & technical output, assimilation of inward technology transfer, R&D collaboration, inward FDI, technological absorptive capacity of teams, interactions between technological actors, catching-up capacity, education & training schemes, organizational learning, and conceptualization capability of teams. The technological knowledge generation can be carried out consequently through stimulating local R&D, building technological catching-up capacity, emphasis on organizational learning, and promotion of skills supply. 2) *Turning ideas into business* which is emphasized in particular due to the resultant concerns about; role of innovative firms in Libyan oil sector, management of resources, information and communication processes, job satisfaction and interpersonal relationship, entrepreneurship activities, role of private business sector, technological interactions, native technology suppliers. Turning ideas into business can be executed accordingly by building innovative organizations, boosting technological entrepreneurship, and commercialisation of innovative efforts. 3) *Driving innovation business* which is specifically considered owing to consequential concerns about; organizational culture in Libyan oil industry, innovation culture and technology institutional set-up. In view of that, driving innovation business can be taken place through enabling innovation culture and strengthening institutional framework.

– *Controlling Activities*: This includes control activities that aim at monitoring and improving innovation performance of Libyan petroleum sector. These control activities have been emphasized due to the necessity of improving sectoral management system in Libyan oil industry, monitoring local petroleum R&D, improving sectoral innovation system. These controlling activities can be done consequently through setting up sectoral system of excellence and auditing & improving technological performance of Libyan oil organizations.

Table 7.1 demonstrates areas of concern, as a result of research findings, along with activities to be achieved accordingly towards developing petroleum technology in Libyan oil sector within the management framework of technology development.

AREA OF CONCERN	ACTIVITY TO BE TAKEN
– Sectoral technology strategy – Sectoral R&D strategy – Organizational R&D strategy – Significance of developing technology in support of national economy – Top management commitment to R&D and developing technology – Role of government in developing technology – Technological opportunities – Innovation initiatives	*Type: Planning Activities* • TARGETING STRATEGIC TECHNOLOGICAL OPPORTUNITIES, through: – Formulating Technology Strategy at Libyan Oil Sector – Formulating Technology Strategy at Libyan Oil Organizations

– Organization involvement in R&D – Individual interest in R&D – Local R&D infrastructure – Capacity for scientific & technical output – Fund of local R&D – Assimilation of inward technology transfer – R&D collaboration – Foreign R&D partnership – Inward FDI for technology development – Technological interactions – Technological absorptive capacity of teams – Catching-up environment – Education & training schemes – Organizational learning – Conceptualization capability of teams – Native R&D skills – Skills supply	*Type: Action Activities* • GENERATING TECHNOLOGICAL KNOWLEDGE, through: – Stimulating Local R&D – Building Technological Catching-up Capacity – Enhancing Organizational Learning – Promoting Skills Supply & Attracting Talents
– Role of innovative firms – Management of resources – Information and communication process – Job satisfaction and interpersonal relationship – Technological entrepreneurship – Technological interactions – Role of private business sector – Involvement of native technology supplier	*Type: Action Activities* • TURNING IDEAS INTO BUSINESS, through: – Building Innovative Organizations – Boosting Technological Entrepreneurship – Commercializing Innovative Efforts
– Organizational culture – Innovation culture – Technology institutional framework	*Type: Action Activities* • DRIVING INNOVATION BUSINESS, through: – Enabling Innovation Culture – Strengthening Institutional Set-up
– Local innovation performance – Local R&D performance – Performance of sectoral innovation system – Management system – International outlook	*Type: Controlling Activities* • MONITORING INNOVATION PERFORMANCE, through: – Setting up Sectoral System of Excellence – Auditing and Improving Technological Performance

Table (7.1): Key Activities of MFTD for Libyan Oil Sector

The set of interrelated activities configured earlier is summed up, as shown in figure 7.1, to constitute the key elements of the MFTD for Libyan oil sector.

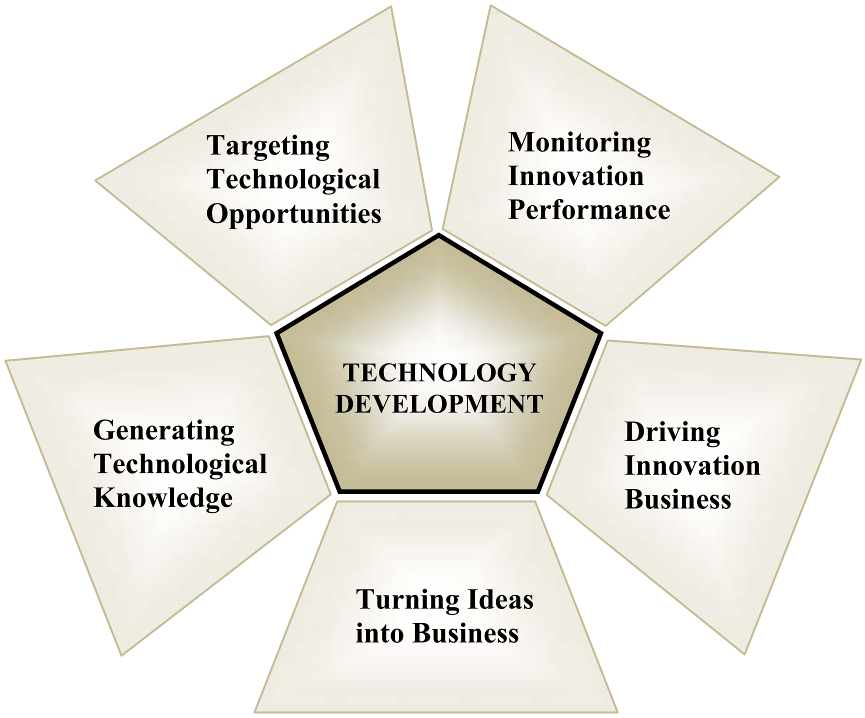


Figure (7.1): Management Framework of Technology Development for Libyan Oil Sector

Activities of MFTD are developed in original aspects to meet the requirements of petroleum technology development in Libyan oil sector in terms of:

- Mechanisms of formulating technology strategy at Libyan oil sector.
- Mechanisms of formulating technology strategy at Libyan oil organizations.
- Mechanisms of stimulating petroleum R&D in Libyan oil organizations.
- Mechanisms of ensuring top management commitment to local R&D in Libyan oil organizations.
- Role of "*Libyan oil industry-national government-local universities*" interface in petroleum technology development.
- Mechanisms of promoting bilateral interactions between Libyan oil industry and local & foreign universities towards petroleum knowledge generation.
- Characteristics and determinants of petroleum R&D partnership for Libyan oil organizations.

- Role of Libyan government towards promotion of petroleum research partnerships in Libyan oil sector.
- Mechanisms of improving R&D infrastructure in Libyan oil sector.
- Mechanisms of involving foreign direct investment in Libyan petroleum R&D.
- Interactions of innovation systems and foreign direct investment for petroleum R&D in Libya.
- Main pillars of building catching-up capacity at Libyan oil sector.
- Mechanisms of building technological catching-up capacity at Libyan petroleum organizations.
- Organizational learning cycle for Libyan oil organizations.
- Mechanisms for enhancing organizational learning in Libyan oil sector.
- Mechanisms to ensure skills supply to various petroleum operations in Libyan oil sector.
- Characteristics of innovative organizations towards technological development in Libyan oil sector.
- Main conditions for entrepreneurship to flourish in Libyan oil sector.
- Main dimensions of successful entrepreneurship in new Libyan oil enterprises.
- Main characteristics of proposed technology park in Libyan oil Sector.
- Mechanisms of developing culture as social control system and improving culture in Libyan oil organizations.
- Determinants of national institutional framework towards developing local technologies.
- Guideline of applying the EFQM excellence model for assessment of innovation performance in Libyan oil sector.
- Determinants of involving the Libyan oil organizations in technology auditing.
- Framework of technology effectiveness audit for Libyan oil organizations.

7.3 TARGETING STRATEGIC TECHNOLOGICAL OPPORTUNITIES

7.3.1 Formulating Petroleum Technology Strategy at Libyan Oil Sector

Importance of formulating petroleum technology strategy in Libyan oil sector comes in effect of; increasing concern about significance of developing petroleum technology in support of less diversified national economy, top management commitment to local R&D and developing technology, and role of Libyan government towards developing petroleum technology.

Managing technological development at Libyan oil sector relies on national government' ability to find a strategic approach to harness the innovative potential of its respective petroleum capabilities. Governmental authorities in Libya can play critical roles in promoting new technology development all the way through evaluation, supporting and participation. In this sense, the Libyan government should have an active part in fostering petroleum technology strategy in Libyan oil sector to encourage developing new technologies. Any plans that could be designed for science and technology at Libyan oil sector will provide a degree of visibility for that sector to prioritize its current commitments and future orientation to meet petroleum technological challenges.

Formulation of petroleum technology strategy at sectoral level of Libyan oil industry is essential to ensure that: 1) All stakeholders are aligned behind the petroleum technological development and work together to turn it into reality under common objectives. 2) All R&D efforts are focused on the highest priority areas of petroleum technology that meet needs of Libya oil sector and secure future value creation. 3) All scientific and technological collaborations resulted lead to a more coordinated approach to petroleum R&D. 4) Effective mechanisms to identify and exploit emerging and generic petroleum technologies are recognized. 5) Effective mechanisms to enhancing petroleum technology transfer are realised. 6) Initiatives of petroleum technology development can yield the greatest economic and social benefits. 7) Significance of petroleum technology development to economic growth of Libya spreads amongst all key actors.

Energy consumption worldwide is soaring as never before driving the global demand for more energy production. Quenching the world's thirst for energy will call for more technological advancements and investments. This may urge Libya, as being an oil and gas producing country, to get involved in some petroleum technological ventures in order to explore and produce efficiently its considerable hydrocarbon potential. The achievement of technological development for various oil and gas operations in Libya depends on the pattern and the defined prerequisites of technological capacity building, the potential capacity of Libyan petroleum industry to acquire and develop the technological knowledge and the impact of Libyan government policies on the incentive system. Furthermore, the petroleum technology strategy at Libyan oil sector serves as a catalyst and an arena where all key players can meet. In other words, it is a drive aims at uniting the Libyan petroleum industry, petroleum research organizations and Local governmental authorities in an effort to solve challenges that should be addressed to ensure positive results of petroleum activities, together with an ambition to build a more focused and structured platform of various petroleum technologies to meet domestic and global energy demands.

In this respect, establishment of petroleum technology strategy at Libyan oil sector can be set based on the structure shown in figure 7.2, which is rooted in experiential work of strategy formulation in Norwegian petroleum sector (2006).

Figure (7.2): Structure of Petroleum Technology Strategy at Libyan Oil Sector

Petroleum technology strategy at Libyan oil sector should be formulated and taken place by integrated efforts of Libyan oil industry, national universities, research institutes and governmental authorities, in accordance with the following phases:

– *Vision and Objectives*: The strategy should define the direction for the work in Libyan oil sector and describe what the end results of planned activities are. The achievement of objectives should result in the fulfilment of what the strategy is made for. The vision could be formulated such as "generating new technology and knowledge to ensure the profitable and sustainable development of the petroleum resources", and the objectives might be for instance as "developing new petroleum technology for deep seismic operations and ensuring export of that technology".

– *Key Challenges*: The strategy should identify a number of key challenges that must be addressed to meet the Libyan oil sector's technological objectives, namely:1) Trend challenges that influence the direction of research and development efforts such as environmental and social concerns, enhancing hydrocarbon recovery, increasing reserve replacement rate, cost-effective technology, etc. 2) Competence challenges that have essential impact on capability of the Libyan oil sector to developing the intended technology, and which may entail interventions of the governmental authorities to establishing technology-related coordination and remove accordingly pertinent obstacles and stumbling blocks. For instance, the interventions could be such as developing the competence for a specific petroleum technology, boosting transfer of a particular technology, enhancing skills supply to Libyan oil industry and mobility of human resources, alleviating constraints to R&D infrastructure, resolving bottlenecks along technology supply chain, etc.

– *Technology Target Areas*: The strategy should encompass the priority thematic areas of technology development that respond to technological objectives and ahead key challenges of Libyan oil industry. In addition, technology target areas are considered the generic framework which all petroleum technological actors of interest should work within. These target areas could be such as environment-friendly technology of enhanced oil recovery, exploration technology and reservoir characterization, cost effective technologies of drilling and well completion, deep water and subsea production technology, gas processing technology, etc.

– *Action Plans*: The strategy should contain action plans which state what actions are going to be taken towards accomplishing the strategy's objectives, by whom, during what time frame, how to be funded, and with what expected results and benefits. Action plans may including, but not limited to, date of beginning new research programmes or ventures, establishing new interactions or coordination, restructuring the key organizations in Libyan oil sector, and changing the organizations' internal culture.

Action plans are important for several reasons, namely: 1) Provide a link between strategy formulation and evaluation & control. 2) Spot what needs to be done differently to meet the strategy's targets. 3) Help both the appraisal of performance and the identification of any required action of remedy. In addition, the explicit assignment of responsibilities for implementing and monitoring the action plans will contribute to better management procedures.

Figure 7.3 shows the collaboration and action plans of petroleum technology strategy that can be taken place at Libyan oil sector.

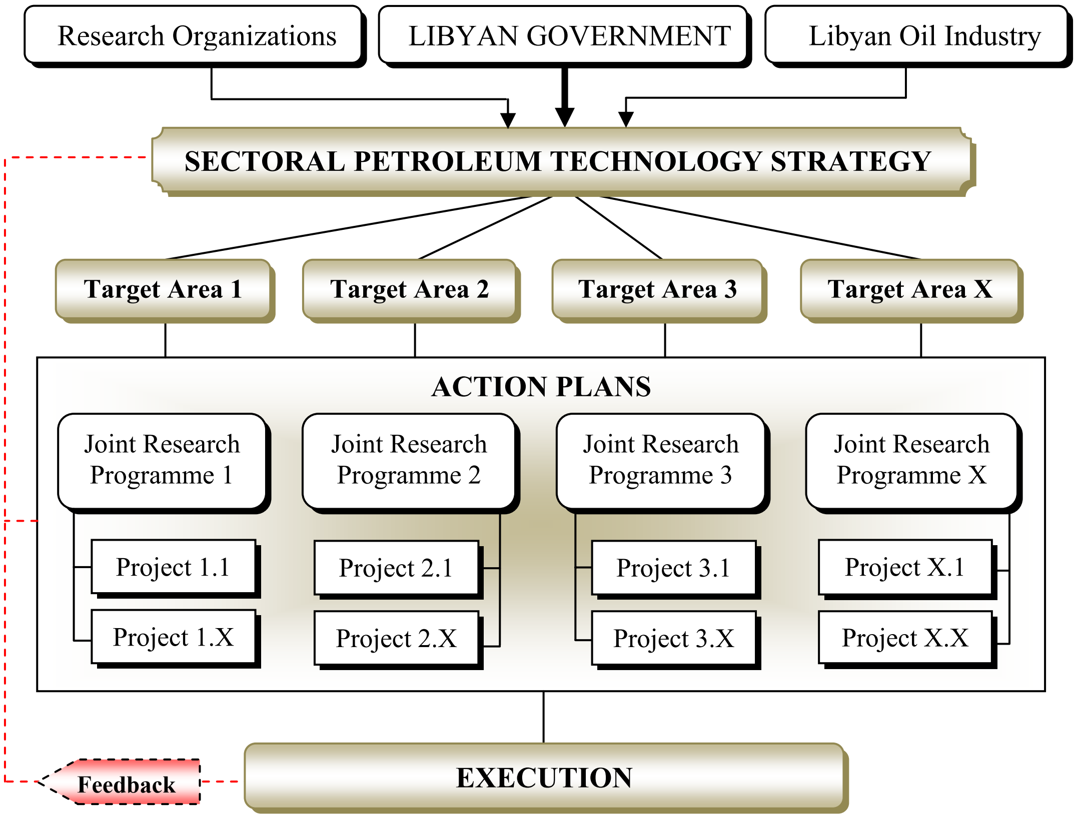


Figure (7.3): Collaboration and Action Plans of Petroleum Technology Strategy at Libyan Oil Sector

– *Execution*: Implementation of technology strategy in Libyan oil sector is a process by which planned activities are put into action through execution of joint research programmes and their budgets. This phase integrates personnel from Libyan oil industry, national universities and research institutes, technology supply industry and national governmental authorities, all together with other essential resources to carry out the scheme of projects execution under supervision of a sectoral steering committee formed intentionally from some elite experts of the key actors in Libyan oil sector. Progress monitoring reports should be taken place on regular basis throughout the execution phase in compatible with the control measures to directly identify variance from the project execution scheme, so that corrective actions can be engaged when necessary to meet the project objectives. Typical monitoring and controlling processes for project execution, which can be used in monitoring and controlling of research projects within the technology strategy of Libyan oil sector, are demonstrated in figure 7.4.

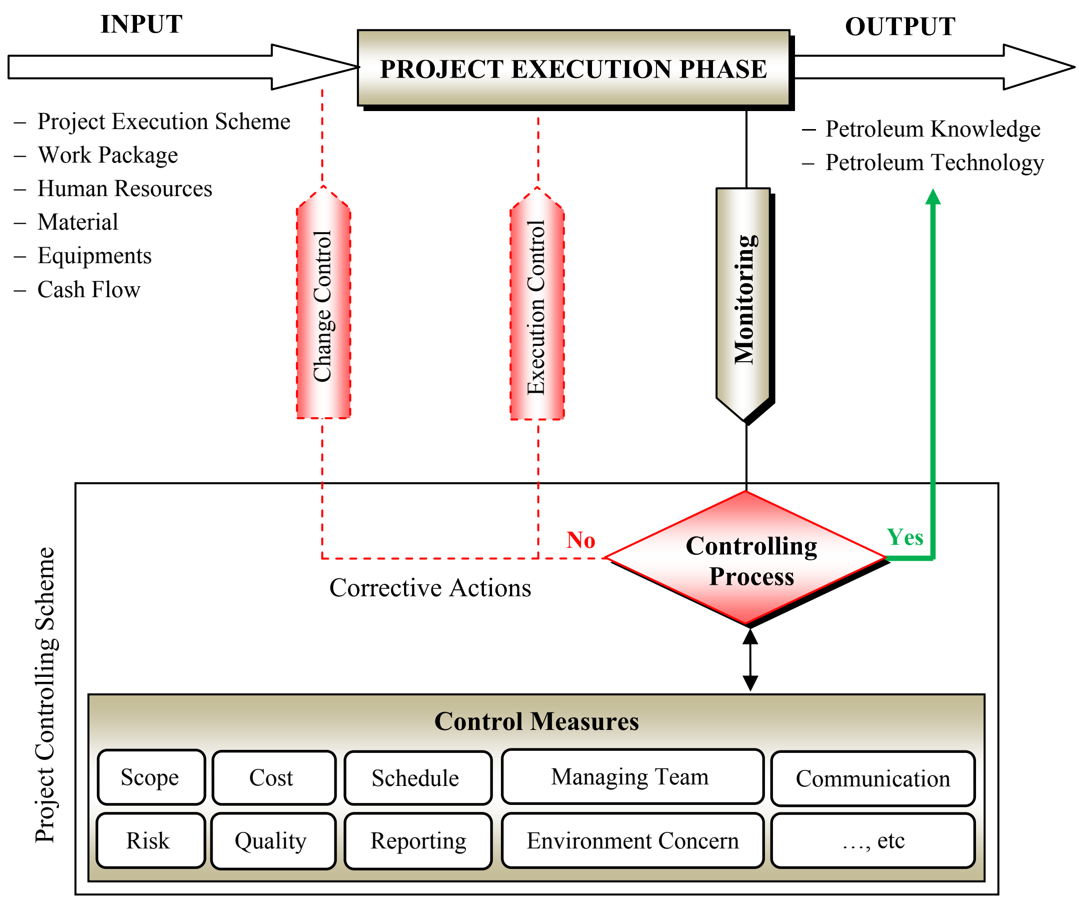


Figure (7.4): Typical Monitoring and Controlling of Research Project for Libyan Oil Sector

7.3.2 Formulating Petroleum Technology Strategy at Libyan Oil Organizations

Petroleum technology strategy at level of Libyan oil organization is the task of building, maintaining and exploiting the organization's technological capitals to attain value-based technological opportunities. This requires extensive foresight about distinctive petroleum technology it can provide, the potential investment opportunities, and where the organization technological position to be in the future.

The business strategy of Libyan oil organization (e.g., operating firms), on the other hand, is to gain a sustainable economic advantage in terms of maintaining the operations of oil & gas production towards sustainable market share. In this sense, effective technology management in Libyan oil organization is based on integrating and linking successfully business and technology strategies at the level of objectives, goals and decision policies, bearing in mind that, technology is a subset of the organization's business. Failure to create such integration is a causal factor towards the declination of the organization competitiveness degree.

Petroleum technology strategy in Libyan oil organization serves as the basis for fundamental business strategy decisions. It helps answer questions such as: 1) which distinctive technological competences are necessary to establish and maintain the organization competitive position? 2) Which technologies should be used to implement core petroleum product design and how should these technologies be embedded in products? 3) What should be the investment level in petroleum technology development? 4) How should various technologies be sourced (internally or externally)? 5) When and how should new petroleum technology be introduced to the market? 6) How should technological innovation be organized and managed?

Moreover, the technology strategy of oil organization should be formulated and established within the framework of technology strategy at Libyan oil sector or national level in order to enable all stakeholders to respond to sectoral or national objectives and key challenges.

Figure 7.5 (p.326) shows an opportunity-based framework for technology strategy formulation that can be used by Libyan oil companies and petroleum research institutes (e.g., Libyan Petroleum Institute) either for upstream or downstream technological opportunities. This technology strategy framework was originated based on the theoretical foundations and empirical perspectives to formulating technology strategy at micro-level (in this regard, see Wheelen and Hunger, 2008; Narayanan, 2001; Khalil, 2000; Burgelman and Rosenbloom, 1999; Ford, 1988).

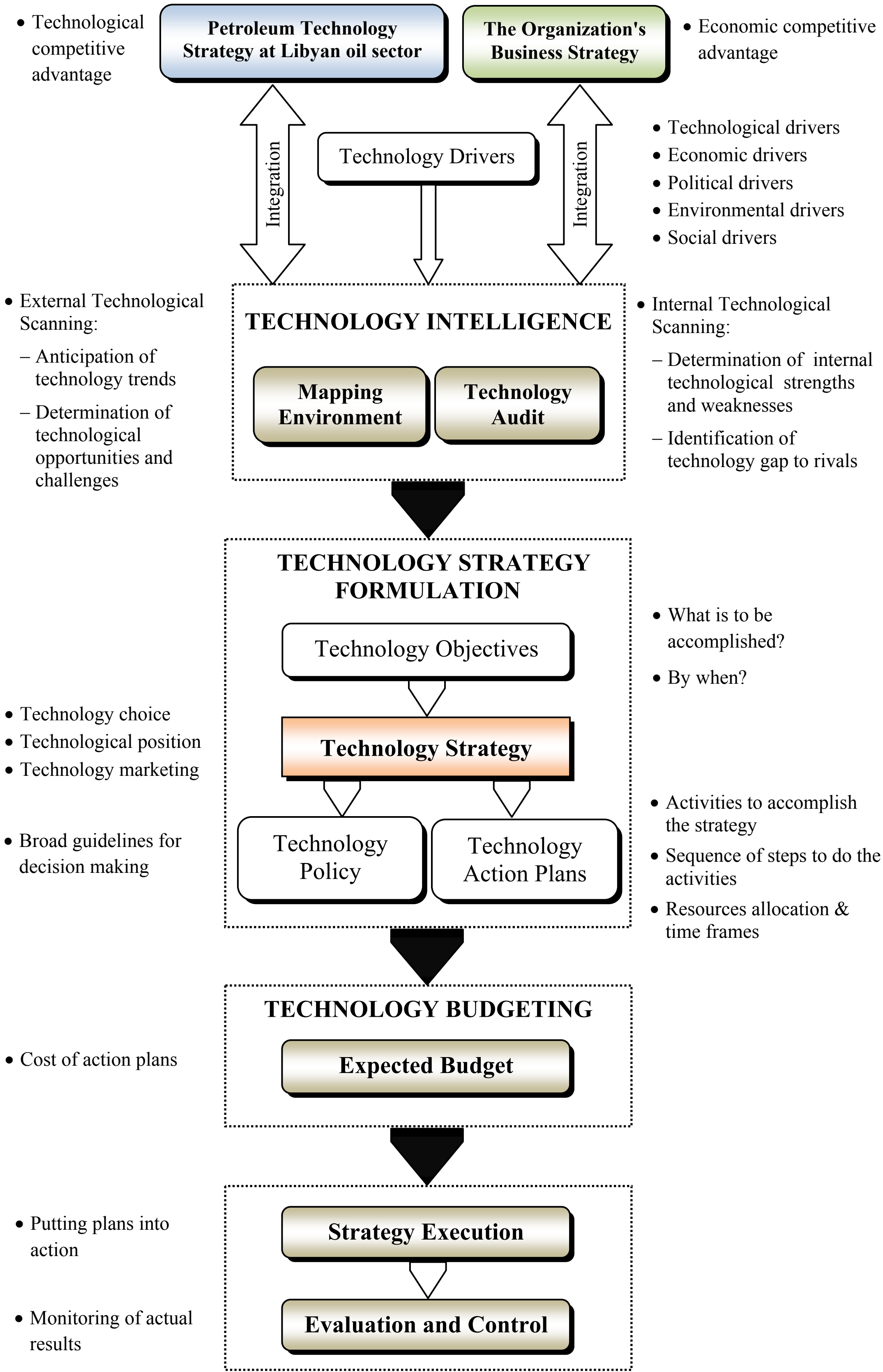


Figure (7.5): Opportunity-based Framework of Technology Strategy for Libyan Oil Organizations

To formulate its petroleum technology strategy, the organization in Libyan oil sector should at first identify the available drivers that promote its involvement in developing a particular petroleum technology. One can outline the most typical drivers of interest as follows:

– *Technological drivers* such as: 1) signals of potential technological change that may sustain technological advantage of the oil organization, 2) market demand for petroleum technology, 3) the organization's technological advancement, 4) seizing opportunities for petroleum technology catching-up, 5) technological competence of the oil organization, etc.

– *Economic drivers* such as: 1) rising costs of petroleum operational inputs, 2) high oil demand and high oil prices, 3) inflow of foreign direct investment into Libyan oil sector, 4) supporting the oil organization's economic competition position, 5) macroeconomic stability in Libya, 6) national GDP diversification and level of national GDP per capita, etc.

– *Political drivers* such as: 1) coping with petroleum technology sanction or embargo imposed on the nation, 2) existence of good governance and rule of law at national level, 3) effective national/sectoral institutional set-up, 4) political conventions and alliances made by Libyan government with other developed countries that include issues of development, 5) local and international energy security, etc.

– *Environmental drivers* such as undermining the local effects of climate change, problems of produced water during petroleum operations, etc.

– *Social drivers* such as: 1) creating new market and job opportunities for nationals, 2) increasing native skills, 3) enhancing sectoral productivity, 4) lower costs of petroleum production and derivatives for the sake of local use, 5) increasing living standard and society wealth creation, 6) shifting to knowledge societies, etc.

The main phases of the opportunity-based framework of technology strategy, designed for Libyan oil organizations, are elaborated as follows:

– *Technology Intelligence*: The primary input into technology strategy formulation is technology intelligence. With respect to Libyan oil organization involves in technology development, this phase should articulate clearly the following issues: 1) what new petroleum technologies are likely to emerge in the near future that might affect the organization oil business? 2) What advances being made in the organization's core technologies, which of its key technologies are matured, and what will replace them amongst internal technologies? 3) What capabilities do competitors have, and how might they use them against the organization? 4) Who is working on petroleum technologies that could benefit the organization, and how might the organization access them? The importance of finding accurate and timely answers to these questions is critical. If the oil organization misses answers to these questions, it may miss the opportunity to exploit new technologies or, by default, lose its position in the marketplace. Thus, technology strategy formulation should be closely linked to technology intelligence.

The opportunity-based framework of technology strategy formulation for Libyan oil organization starts with technology intelligence which comprises: 1) *Mapping technology environment* in terms of external scanning to anticipating petroleum technology trends or detecting signals about potential for technological change (e.g., competitor's new emerging technologies); determining potential opportunities for petroleum technology investment that the organization may obtain either through market pull (e.g., owing to competitor incapability to meet such market demand) or through the organization technology push made by its core competencies and outstanding technology advantage; and identifying possible challenges which may originate from rivals and new entrant threats, and from inevitable support to the organization's competitive position. 2) *Technology audit* in terms of internal scanning which encompasses; determining strengths and weaknesses of the organization's technological competencies to cope with target petroleum opportunities and challenges; and identifying the organization's existing and long-term technology gap relating to its rivals.

– *Technology Strategy Formulation*: Following the identification of technology objectives which tell what is to be accomplished and by when, the petroleum technology strategy should contain: 1) *Technology choice*: the organization must decide on the appropriate form of new petroleum technology it should select for developing (e.g., product versus process, and make or buy). 2) *Technological* *position*: whether to seek technology leadership (i.e., first mover), followership (i.e., wait and improve), or imitation. 3) *Technology marketing*: whether to seek product differentiation or cost orientation, and large market share or niche market. In this context, the matrix of technology market strength and petroleum technological capability, which has been adapted from Lowe (1995) and shown in figure 7.6, would be of much benefit to link the current petroleum technological capability of Libyan oil organizations to their technological objectives by deciding: 1) what petroleum technologies have to be bought, developed or improved? 2) When technological capability should be developed? 3) When technological partnership should be taken place? 4) When technological opportunities should be targeted? 5) When technology market niche should be tackled?

TECHNOLOGY MARKET STRENGTH			
Strong	**Buy Technology**	**Develop Technological Capability**	**Concentrate on Opportunity**
Average	**Keep Out**	**Look for Opportunities**	**Strengthen Marketing Function**
Weak	**Keep Out**	**Find Market Niche**	**Look for Partners**
	Weak	Average	Strong

PETROLEUM TECHNOLOGICAL CAPABILITY

Figure (7.6): Matrix of Technology Market Strength and Petroleum Technological Capability

Having formulated the petroleum technology strategy, the Libyan oil organization should outline the technology policy which is a broad guideline for decision making which ties the formulation of strategy with its execution. In other words, Libyan oil organization should use technology policy to ensure that technology-related personnel throughout the oil organization make decisions and take actions that meet technological objectives. Technology action plans should be consequently prepared to address; what are the activities needed to accomplish the strategy and what is the sequence of steps necessary to do these activities, the resources allocation, and time frames required to carry out the action plans. Budgeting of action plan costs is of a key role to put the petroleum technology strategy on track of execution with no or fewer drawbacks.

7.4 GENERATING PETROLEUM TECHNOLOGICAL KNOWLEDGE

Technological rapid changes increasingly drive firms to generate new knowledge in order to remain competitive. Nowadays a much heavier emphasis is being placed on generating technological knowledge as being crucially important for the success of product and process innovations (see UN Millennium Project, 2005; Berends et al., 2006; Nieto and Quevedo, 2005).

In this sense, generation of knowledge in Libyan oil organizations can be carried out through: 1) Stimulating local R&D. 2) Building technological catching-up capacity. 3) Enhancing organizational learning. 4) Promoting skills supply & attracting talents.

7.4.1 Stimulating Petroleum Research and Development

The research concept is primarily a quest for knowledge or a search for underlying scientific principles in the area of knowledge investigated. In addition, the research and development expenditure shapes now a considerable proportion of a firm's funds across all industrial sectors as companies principally realize that new products can provide vast competitive advantages (see DTI, 2006 and NSB, 2006).

Therefore, the role of R&D in petroleum knowledge acquisition, generation and exploitation is shown in figure 7.7, which was adapted from Davenport, et al. (2003).

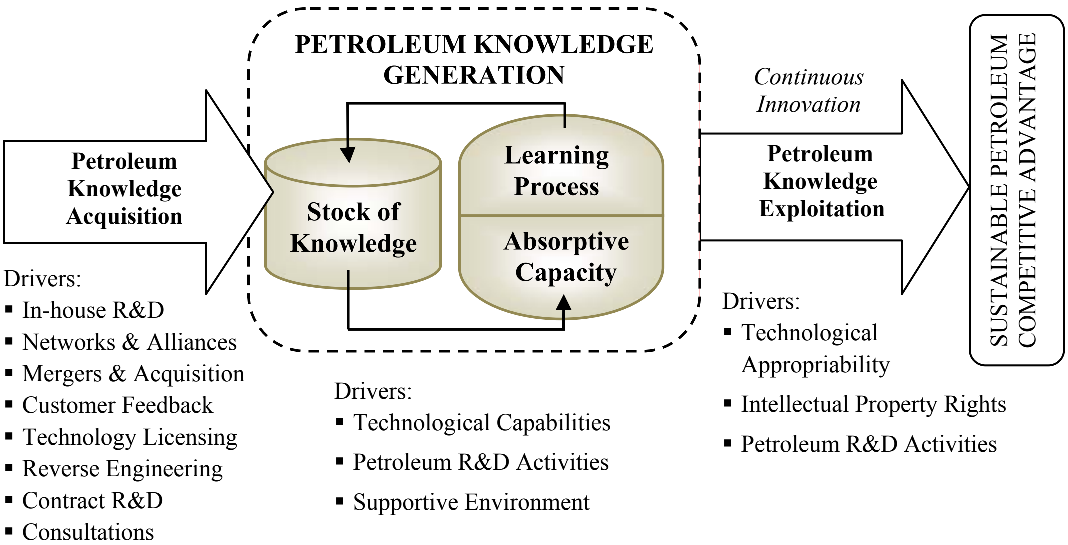


Figure (7.7): R&D Essential to Petroleum Knowledge Generation

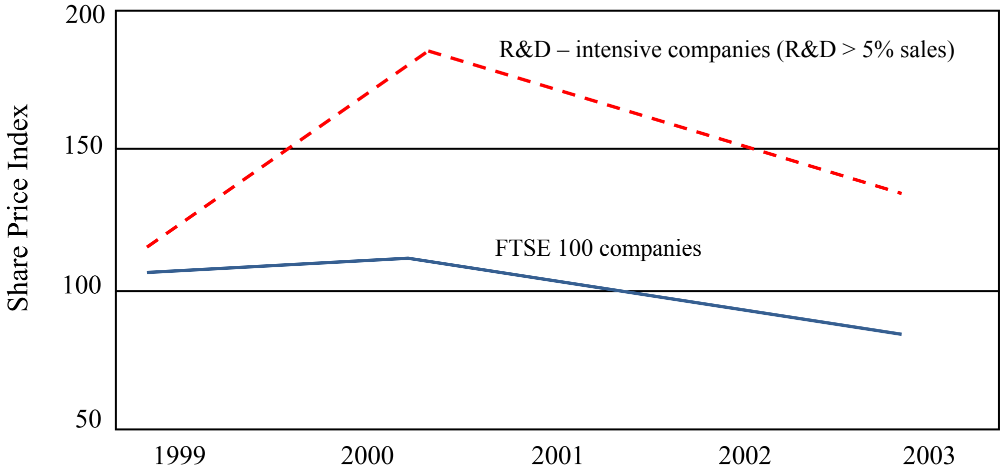
Petroleum R&D activities, which traditionally comprise the phases of fundamental research, applied research, and experimental development, should be paid a much more attention in Libyan oil industry as being a major source for new petroleum ideas and technological knowledge.

Hence, stimulating petroleum R&D is vital to Libyan oil organizations, which are in fact suffering: 1) weak involvement in R&D, 2) low top management commitment to R&D, 3) poor funding for R&D activities, 4) rare R&D interactions between the key players in Libyan oil industry, 5) high barriers to successful R&D projects, 6) unseemly learning climate within the research community, 7) temperate barriers to inwards FDI in favour of applied research, and 8) poor scientific and technological output in terms of rate of producing research papers and articles, technical bulletins, technical standards, technical directives, scientific books, technical performance reports, applied and granted technological patents, technical copyrights and trademarks, rate of issuing know-how licences, and rate of performing technical consultations and industrial designs (see status of in-house R&D, pp. 274-280).

The stimulation of petroleum R&D in Libyan oil organizations can be take place in terms of:

– *Ensuring Top Management Commitment to Petroleum R&D*: By definition, the research is uncertain based on exploring things that are not yet known, as well as costly and time-consuming activities. Therefore, this may lead one to think that research can not be managed and is not worthy to consider for a long period of time, and organizations should not try to do so. Rather, R&D needs to be managed according to the specific heritage and resources of the company in its competitive industry because each company and every competitive environment is unique and has its own state of change (in this regard, see Trott, 2008).

Moreover, there is overwhelming evidence to suggest that industrial technological research can indeed be managed and that most of those organizations that spend large amount of money on R&D do so extremely well. For instance, figure 7.8 (p.332) compares the share price performance of R&D-intensive firms with 100 firms of Financial Time Stock Exchange (FTSE).



Source: Trott (2008)

Figure (7.8): Comparison of Share Price Performance of R&D-intensive Firms

Thus, top managers in Libyan oil organizations should: 1) Devoting to petroleum R&D activities on long term or strategic issues. 1) Valuing and managing portfolios of real options in accordance with impact of volatility, adaptability and competitive responsiveness. 2) Be confident that petroleum R&D strategic planning is more appropriately for the organization to meet its petroleum technological objectives rather than by chance or good fortune. 3) Assuming that petroleum R&D investment is a fundamental pillar for growth or even survival and the difficulty lies in where precisely the investment should be, which petroleum technology projects to invest in, and when to stop supply money into a project that looks likely to fail but could yet deliver enormous profits. 4) Avoiding the risk of exploiting petroleum R&D resources in directions which may not achieve the performance advantage for effective growth. 5) Taking into account that globalization provides opportunities for Libyan oil organizations but also brings more serious challenges.

– *Strengthening Public Fund in Petroleum R&D:* The petroleum research in Libyan oil industry is mainly government-funded research. These activities are in fact suffering a weak public fund. For instance, the mean budget allocated to R&D during the period 2003-2007 was about 0.48% of mean total of sector budget (see expenditures distribution in Libyan oil sector, pp.289-290). This size of R&D budget herein indicates that there is no vital role assigned to in-house petroleum research to play in solving technical problems of Libyan oil industry.

On contrary, substantial government funds are spent every year worldwide on undertaken R&D activities at universities and institutes, or performed on the basis of collaboration between universities and industry (see OECD, 2006; NSB, 2006; OECD, 2002a; Cohen et al., 2002). In this context, several country studies (e.g., Finland and Japan) showed that government funding not only allowed firms to accelerate the completion of R&D projects (i.e., enabling them to introduce new products or services into the market sooner), but also encouraged them to launch projects that entailed greater technological challenges that they might otherwise have pursued (see OECD, 2006).

The dilemma, in this regard, is that the benefits associated with public spending on fundamental research are less obvious comparing, for instance, to those from health or education spending. Within this context, some studies have been made to measure the economic and social impact of publicly funded R&D (see Martin, 1998; Martin et al., 1996; Smith, 1991; Bergman, 1990). These attempts show a large positive contribution of academic research to economic growth. In this sense, there are various types of contributions that public funded research makes to economic growth: 1) Increasing the stock of useful knowledge. 2) Training skilled graduates. 3) Creating new scientific instrumentation and methodologies. 4) Forming networks and stimulating social interaction. 5) Increasing the capacity for scientific and technological problem-solving. 6) Creating new firms (spin-offs) as a benefit of government-funded research.

An investment in petroleum R&D, however, usually yields a return only in the longer term. The size of this return is difficult to predict. Nor is it simple to create any quantified measure for the overall effectiveness of petroleum R&D investment in the past which could be considered as an indication of what to be expected in the future because the circumstances and uncertainties surrounding any petroleum investment project differ each time. Therefore, for the most effective use of petroleum R&D financial resources in Libyan oil sector, it might be essential to recognize those factors to which the financial success of the petroleum investment is responsive, and try consequently to exploit a part of these resources into reducing the uncertainties in those critical areas before committing major investment for future development. This can be done in terms of exploratory study which may result in adjustments to the objectives and time frame of the petroleum research project.

Hence, by increasing the public funded research in Libyan petroleum sector, the frontier of scientific understanding would be extended and the pool of economically useful information for Libyan oil organizations can be expanded. All of that, in turn, will help growing the sectoral body of petroleum knowledge.

– *Enhancing Local Triple-Helix Interactions*: It is fundamentally recognized that interactions provide the actors the opportunity to share and exchange the thoughts, potential ideas and views. The technological knowledge and innovation are generated, based on the triple helix model, by the combination of relations and interactions between university, industry, and government (in this regard, see Etzkowitz and Leydesdorff, 1996, 1997, 2000; Fagerberg, 2005; Malerba, 2004).

Therefore, the performance of technological innovation in Libyan oil sector should be relied basically on the intensity and efficiency of the interactions between the sector's key actors involved in generation and diffusion of petroleum knowledge.

The interface of Libyan oil industry, local universities, and national government has a considerable role to play in the development and utilization of petroleum technologies. The Libyan government's role is to emphasize the national commitment and awareness by enhancing the flow of knowledge and skills supply between universities and Libyan oil industry, and by protecting important social and environmental objectives that may conflict with goals of Libyan oil organizations. More specifically, the Libyan government can play some explicit roles in promoting petroleum R&D and technology acquisition, namely: 1) a supportive role to finance crucial petroleum research activities and drive technology transfer from universities to Libyan oil industry, 2) a participative role to carry out petroleum R&D in association with local universities and Libyan oil industry, and 3) an appraiser role to build an understanding of the importance of a particular novel petroleum technology to Libyan oil industry, so that it can develop the proper mechanisms to enhance success of that technology. On one hand, the local universities have two major tasks; education and research. They also yearn for research grants and empirical knowledge of Libyan oil industry. On the other hand, the Libyan oil industry has two main requirements from universities: 1) Educated individuals who can perform in various operations of petroleum industry. 2) Access to petroleum research and potential inventions for the sake of mutual benefits.

Figure 7.9 shows the role of Libyan oil industry-government-local universities that should be considered towards petroleum technology development.

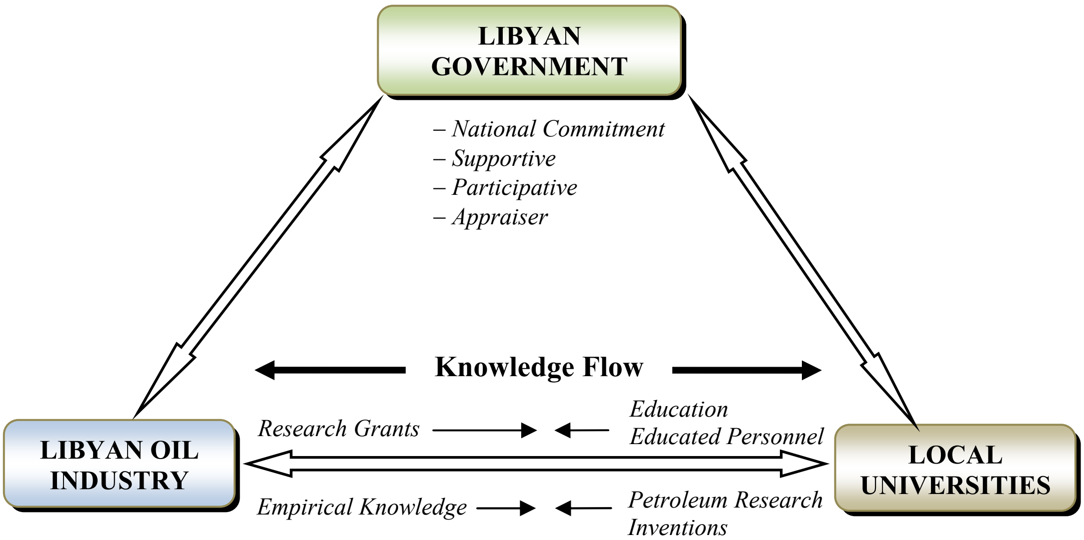


Figure (7.9): Technological Role of Local Triple Helix Interface

The interactions between Libyan oil industry and local & foreign universities should be supported and appeared in many aspects. Central among these aspects is the research collaboration which can be performed in pursuit of petroleum knowledge generation. Figure 7.10 shows typical areas of petroleum research that suppose to be conducted between Libyan petroleum industry and universities.

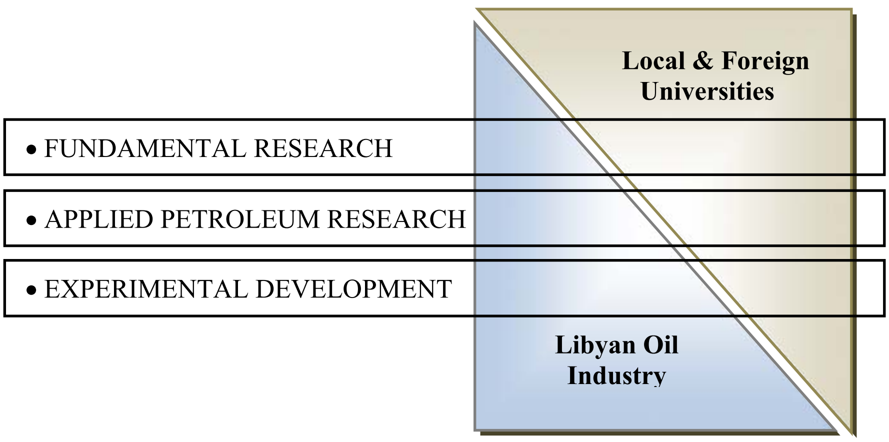


Figure (7.10): Typical Areas of Petroleum Research Emphasis in Universities and Libyan Oil Industry

However, the bilateral interactions between the Libyan oil industry and local & foreign university towards petroleum knowledge generation should be focused on: 1) Encourage conducting joint petroleum research projects and scientific publications as well as to allow industrial and academic researchers to engage in face-to-face knowledge exchange. 2) Enable researchers of Libyan petroleum industry to seek fundamental understanding and to involve in other issues that usually pertained to basic research, such as deep questions of logic, analysis and computation, and complex scientific methodologies. 3) Help academicians working in applied petroleum research to develop significantly new designs, concepts, methods and prototypes. 4) Give rise to double-way knowledge flows through a well connected network which would be largely useful and of mutual benefit for both sides. 5) Assist Libyan oil organizations recruiting qualified researchers, engineers and designers from universities.

Thus, to promoting these bilateral interactions which witness occasional rate of performance (see scientific and technological interactions, pp.286-287), both parts should work together towards: 1) More problem-solving joint research 2) More joint scientific publications. 3) Developing mutual understanding to the basis on which the contribution of each part towards successful petroleum R&D can be made. 4) Joint studies to formulate national or sectoral R&D strategy. 5) Joint studies to enhance commercialization of Libyan universities research. 6) Mutual education and training programmes to build petroleum skills. 7) Well-designed information network for dual knowledge flow. 8) Frequent joint scientific events such as conference, symposiums, and workshops.

– *Emphasizing Petroleum Research Partnerships:* Research partnership is defined broadly as an innovation-based relationship that involves, at least partly, a significant effort in research and development. In this respect, considerable attention is paid to collaboration in numerous organizations in order to reduce the financial burden and produce successful technology as the costs, risks, complexity and time-scales of substantial R&D programmes have escalated largely (in this regard, see Hagedoorn et al., 2000; Tidd et al., 2005).

The Libyan oil organization that aspires to participate in petroleum research partnership should be involved in order to: 1) Access external complementary capabilities and resources to develop a technological platform capable of solving problems of petroleum operations. 2) Expand the scope of effective research activities in Libyan petroleum industry. 3) Share high petroleum R&D costs, lower associated risks, and subdue competition of rivals. 4) Increase efficiency and synergy of petroleum research output through information sharing and knowledge spillovers of partnership networks. 5) Create new petroleum investment in high-opportunity and high-risk research activities. 6) Promote organizational learning, internalize core competencies, and enhance competitiveness of the organization.

In this context, partnership or collaboration between Libyan oil organizations or with other international oil organizations can be characterized in many different ways. Table 7.2 shows the different typical forms of research partnership or collaboration that can be created in Libyan oil sector as adapted from Tidd et al. (2005).

TYPE OF COLLABORATION	TYPICAL DURATION	ADVANTAGES	DISADVANTAGES
Subcontract	Short term	– Cost and risk reduction – Reduced lead time	– Search costs, product performance and quality
Licensing	Fixed term	– Technology acquisition	– Contract cost and constraints
Consortia	Medium term	– Expertise, standards, and share funding	– Knowledge leakage – Subsequent differentiation
Strategic Alliance	Flexible	– Low commitment – Market access	– Potential lock-in – Knowledge leakage
Joint Venture	Long term	– Complementary know-how – Dedicated management	– Strategic drift – Cultural mismatch
Network	Long term	– Dynamic, learning potential	– Static inefficiencies

Table (7.2): Typical Forms of Research Collaboration

Producing new scientific knowledge and learning in Libyan oil sector can be achieved by petroleum R&D partnership. Thus, Libyan oil organizations aim at incorporate in petroleum knowledge creation are required to emphasize partnership and collaboration within their business strategies along with a deliberate decision-making that counterbalance between all associated advantages and disadvantages.

The role of Libyan government to promote and support petroleum research partnerships in Libyan oil sector should be taken place in terms of: 1) Fixing potential failures in crucial petroleum R&D investments. 2) Speed up technological innovations that aim at improving efficiency of petroleum operations. 3) Increase technological knowledge exchange among petroleum firms, universities, and public research institutes (e.g., Libyan Petroleum Institute).

Potential determinants of petroleum R&D partnership in Libyan oil sector are partly interdependent and may fall into: 1) Behaviour aspect undertaken by all partners during partnership life cycle such as trust exists between them, motives to learn and involvement in the joint processes. 2) Structural aspects of learning and development such as: nature of knowledge (tacit or codified) and skills engaged or developed in the partnership; characteristics of the formal agreement that become factors of stability; configuration of partnership or scope of functions; distribution of tasks among partners; number of partners; complementary petroleum assets and R&D experience (in this regard, see Ingham and Mothe, 1998).

Using external knowledge resources in petroleum R&D activities of Libyan oil sector is a multifaceted issue since a number of determinants are arisen to settle on the optimal degree of openness in the petroleum R&D collaboration. Such degree, therefore, influences the decision of the Libyan oil organization on whether to collaborate widely with external partner(s) or not. The main determinants of openness in petroleum R&D collaboration are as follows: 1) Absorptive capacity of the Libyan oil organization to recognize the value of external knowledge, assimilate it and exploit it in terms of petroleum applications. 2) The capability of the Libyan organization to protect the generated knowledge and innovation from imitation. Thus, the scope in which petroleum knowledge and innovation can be protected from imitators depends on features of the Libyan oil organization's core knowledge (tacit or codified knowledge) and the effectiveness of national legal protection. 3) Access to complementary petroleum knowledge that can add value and match the existing petroleum knowledge within the Libyan oil organization. 4) Cost and risk that can be shared by the partnership. 5) The Libyan oil organization's strategic considerations, in this regard, see Teece et al. (1997) and Knudsen (2006).

– *Improving Petroleum R&D Infrastructure:* Accelerated technology development and the globalization of trade and investment have increased the importance of technological infrastructure as a source of competitive advantage, creating new needs and new opportunities for building technological capabilities (see Justman and Tuebal, 1995).

In Libyan oil sector, physical petroleum R&D facilities are more available than intellectual facilities. In specific, the Libyan Petroleum Institute (LPI) is very well-equipped with petroleum R&D physical facilities than national oil companies. This is essentially due to difference in the nature of current work performed by each part. To conclude, both key players suffer shortage of R&D intellectual facilities to different degrees (see structure of R&D facilities in Libyan oil sector, pp278-279).

Improving petroleum R&D infrastructure, as being an integral part of the entire technical infrastructure of Libyan oil sector (i.e., R&D, exploration, production, manufacturing, and marketing infrastructures), can be taken place through improving of: 1) *Physical infrastructure* which comprise major equipment acquired for petroleum R&D including fixed and moveable instruments and laboratories for various operations, and conventional devices & facilities (i.e., communications, transportation, power, etc.). 2) *Intellectual infrastructure* which encompass human capital infrastructure (i.e., human resources pool of researchers, engineers, and technicians), and institutional infrastructure (e.g., intellectual property rights, information databases, publication system, metrology and calibration system, benchmarking system, quality improvement system, peer review system, performance appraisal system, technology intelligence system, etc.).

Moreover, building or improving R&D infrastructure in Libyan petroleum sector is a joint mission of governmental authorities, oil companies and research organizations. The Libyan government role is to support building the public research infrastructure, develop the proper institutional framework which can benefit all key players, and provide the Libyan oil companies with the necessary fund to improve their physical and intellectual infrastructures.

– *Involving Foreign Direct Investment in Local Petroleum R&D:* Foreign direct investment (FDI) is a key ingredient of economic growth, employment, technological development and spreading of managerial and marketing skills. FDI makes countries compete in an increasingly globalised world. Foreign direct investment in research and development can help countries strengthen their innovation capabilities, enabling them to perform more demanding functions, handle more advanced equipment and make more complex products. But these benefits do not accrue automatically. The requirements for entering the game are demanding, and most developing countries have not taken part in it (see UNCTAD, 2005b; OECD, 2000).

Inward petroleum FDI for technology development in Libya is suffering numerous barriers. This drives the majority of foreign oil companies to invest mainly in petroleum exploration and production activities (see type and mode of entry of FDI in Libyan oil sector, pp.295-297). The high barriers, in this respect, are existed in terms of: 1) lack of Libyan government interest & commitment to encourage FDI in R&D, 2) weak local interactions between foreign oil companies, universities and research institutes, 3) low level of native research output (i.e., significance & quality), 4) limited Local R&D infrastructure, 5) weakness of Libyan finance infrastructure to deal with flow of inward FDI, 6) management problem in general within Libyan oil industry, and 7) inappropriate research business environment in Libya (see status of FDI in Libyan oil sector, pp.295-298).

In view of that, the government authorities in Libya have a crucial role to play for encouraging inflow of FDI to Libyan petroleum sector for R&D. This role can be accomplished in terms of: 1) Building good international research reputation. 2) Improving managerial system of Libyan oil industry. 3) Enhancing indigenous R&D infrastructure. 4) Increasing the government interest and commitment to encourage FDI in R&D. 5) encouraging native individual interest in R&D 6) Formulating effective sectoral strategy of technology development. 7) Increasing interactions among key players of knowledge generation. 8) Strengthening the local infrastructure of finance institutions to support FDI-related funding activities. 9) Reinforcement the institutional framework for local innovation (see priorities of encouraging FDI in technology development at Libyan oil sector, p.298)

The inward FDI in Libyan oil industry can contribute to national growth through its role as a channel for transferring petroleum technology from industrialized nations to a developing country. The inward FDI can increase the rate of technical progress in Libyan oil sector through a "*contagion*" effect from the more advance petroleum technology and management practices used by foreign oil firms. This contagion or knowledge spillovers can lead to improvements in productivity and efficiency in Libyan oil organizations in several ways. In its simplest form, knowledge spillovers can be taken place when national oil companies improve their operational productivity by acquiring some petroleum technologies used, for instance, by multinational oil corporation (MNOC) operating in Libya. Another form arises when Libyan oil firms are forced to use existing petroleum technologies and resources more efficiently or to seek out more supportive petroleum technologies to cope with increased demand for oil and gas (in this regard, see Findlay, 1978).

The most determinates of knowledge spillovers magnitude that can be occurred by foreign oil companies in Libya are in terms of: 1) technology gap between local and foreign oil firms, whereas knowledge spillovers magnitude depends on capability of Libyan oil organizations to absorb foreign petroleum technology, and 2) investment climate in Libyan oil sector; whereas a liberal investment climate, without conditions such as mandatory partnership and domestic content requirements, would tend to generate stronger knowledge spillovers because it is more likely to attract more dynamic petroleum FDI that has a number of attractive qualities such as large and economies of scale, best management practice and highly efficient petroleum investments (in this regard, see kokko et al., 1996; Moran, 1998).

The foreign direct investment in R&D has risen considerably over the last decades. The industrial firms invest in R&D sites abroad either in order to augment their knowledge base or in order to exploit it. The basic motivations and drivers that can attract foreign oil firms to conducting petroleum R&D in Libya are fall into: 1) *demand-oriented drivers* include special petroleum technologies needed by the Libyan oil industry, which require modifications of the foreign firm's products; or restrictions made by the Libyan government, such as local content requirements, tax, and fulfilment of standards, and 2) *supply-oriented factors* include highly sophisticated foreign scientific infrastructure such as new regional technological competence centres which takes advantage of Libyan oil scientific and knowledge inputs and availability of well-educated Libyan R&D specialists having low wages (in this regard, see Granstrand et al., 1992; Dunning and Narula, 1995; Kuemmerle, 1999).

Inward FDI for research and development in Libya could lead to structural changes in the national & sectoral innovation systems of Libya (NIS &SIS). Foreign affiliates that might conduct petroleum R&D become a part of the enterprise segment of the NIS and SIS of Libya and interact to varying degree with national oil firms, national research institutions, National Oil Corporation of Libya (NOC) and the Libyan government. These foreign affiliates will provide channels of resource-sharing between the multinational oil companies (MNOC) and the Libyan country, affecting learning and innovation in the latter. As MNOCs allocate more petroleum R&D resources to the local economy, the NIS and SIS of Libya become increasingly linked with global R&D network of the MNOC and with corresponding innovation systems elsewhere. Figure 7.11 shows the interactions that should be taken place in Libya between the innovation systems and FDI for research and development.

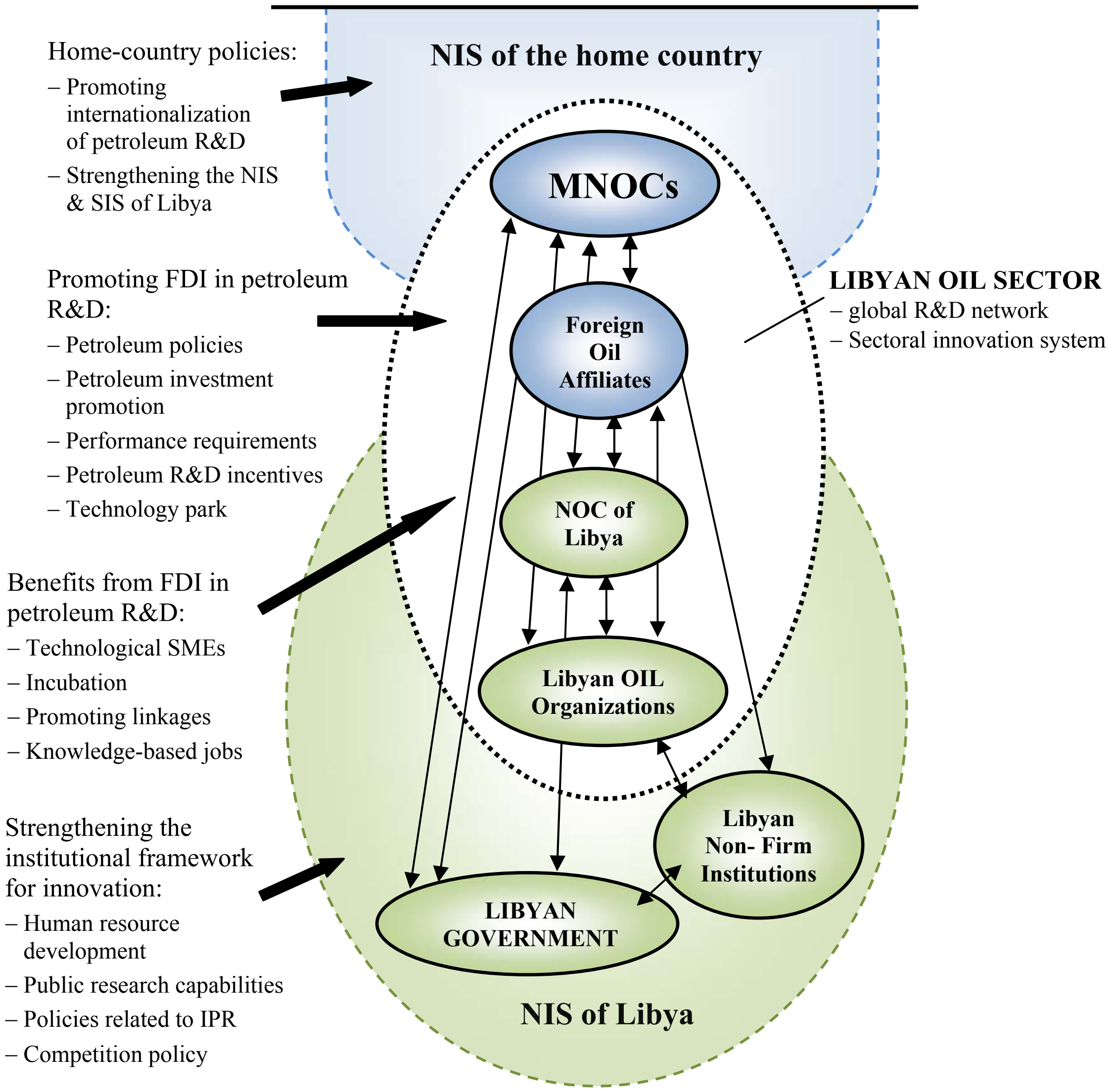


Figure (7.11): Interactions of Innovation Systems and FDI in Libyan Oil Sector

In conclusion, stimulation process of research and development in Libyan oil sector towards petroleum technology development in terms of ensuring top management commitment to R&D, reinforcing of public fund in petroleum R&D, enhancing local triple helix interactions, emphasizing petroleum research partnership, improving local R&D infrastructure, and involving FDI in local R&D, is depicted in figure 7.12.

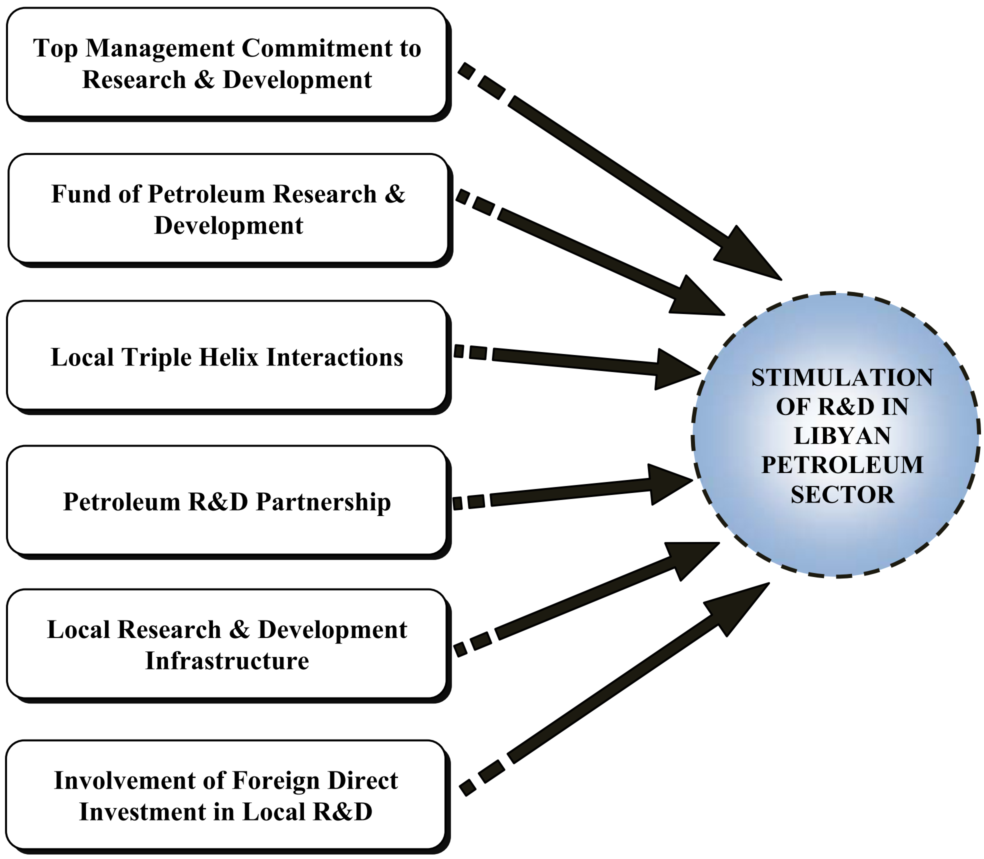


Figure (7.12): Stimulation Process of Petroleum R&D in Libyan Oil Sector

7.4.2 Building Technological Catching-up Capacity

Building Catching-up Capacity of Libyan Oil Sector:

In today's knowledge-based economy, technological capabilities play vital role to performance of national economies and to diffusion of emerging technologies worldwide. The developing countries' prospects for catching-up with more advanced countries in productivity and income hinge increasingly on their ability to rapidly build up competences. This places domestic knowledge systems at the core of industrial development strategies. In addition, owing to the cumulative nature of learning, differences in the rate of accumulation of technological capabilities have an inherent tendency to translate into gaps in economic prosperity across countries. Narrowing these gaps requires sustainable catch-up efforts of various kinds. Pivotal among these is the swift accumulation of technological capabilities (UNIDO, 2005).

The technological catching-up process in Libya face many stumbling blocks in accordance with the country low competitiveness indices, which were published by the World Economic Forum (2007), namely: I) institutions index (3.8/7.0), II) infrastructure index (2.5/7.0), III) market efficiency index (3.4/7.0), IV) business sophistication index (3.6/7.0), V) technological readiness index (2.5/7.0), and VI) innovation index (2.8/7.0). According to aforementioned reference, the most problematic factors for doing business in Libya, arranged orderly, are: 1) Inadequate supply of infrastructure. 2) Access to financing. 3) Inefficient government bureaucracy. 4) Corruption. 5) Policy instability. 6) Restrictive labour regulations. 7) Inadequate well-educated workforce.

In this context, the composite pillars that are appeared to be critical for building catching-up capacity of Libyan oil sector are articulated as follows:

– *Stock of petroleum knowledge*: By far the most important pillar, comprising variables highly correlated with the creation, diffusion, and use of knowledge, such as: 1) education, 2) petroleum research and development, 3) scientific publications, 4) innovation, 5) information and communications technology infrastructure, and 6) quality management.

– *Inward openness*: This pillar is a vital channel for petroleum technology transfer across Libyan oil sector, and highly affected by: 1) inward foreign direct investment, and 2) import trade.

– *Governance*: The importance of governance, institutional set-up, and policies in giving economic incentives for creation and diffusion of knowledge is generally acknowledged. This pillar contains some aspects such as: 1) protection of property rights (i.e., the degree to which the Libyan laws protect private property rights and the degree to which the Libyan government enforces those laws), 2) protection of human rights (i.e., refers to physical integrity rights including rights to freedom from extrajudicial killing by the Libyan government officials without due process of law, disappearance due to political motivations, torture, and political imprisonment), 3) regulatory burden (i.e., how easy or difficult to open and operate a business in Libya), 4) imperial courts (i.e., whether a trusted legal framework exists in Libya for private business to challenge the legality of government actions or regulation), 5) extent of informal market (i.e., extent of corruption which reflects the frequency of corrupt payment, the value of bribes paid, and the resulting obstacle imposed on businesses), and 6) rule of law & order which refers to the degree to which the Libyan citizens are willing to accept the established institutions, to make and implement laws and adjudicate disputes.

– *Political structure*: This pillar is responsible for the political stability of Libya and in turn its oil sector, once it is well designed and established. It comprises: 1) the extent of democracy and autocracy (i.e., institutionalized democracy is defined as one in which political participation is fully competitive, while institutionalized autocracies sharply restrict or suppress competitive political participation), 2) political constraint (i.e., the extent of veto power over policy change), 3) political competitiveness (i.e., reflects competitiveness of elections into legislative branches and competitiveness for posts in executive branches of government), 4) political rights (i.e., enable Libyan people to participate freely in the political process through the right to vote, compete for public office, and elect appropriate representatives), and 5) civil liberties (i.e., allow for the freedom of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the government).

– *Financial system*: This aspect can be captured by the amount of capitalization of various companies listed in domestic stock exchange, domestic credit to private business sector (i.e., refers to financial resources provided to the private oil sector), and interest rate spread which measures the efficiency of financial system and refers to lending rate minus deposit rate.

Figure 7.13 (p.346) illustrates the main pillars of building catching-up capacity at Libyan oil sector which were developed based on the study done by the United Nations Industrial Development Organization (2005).

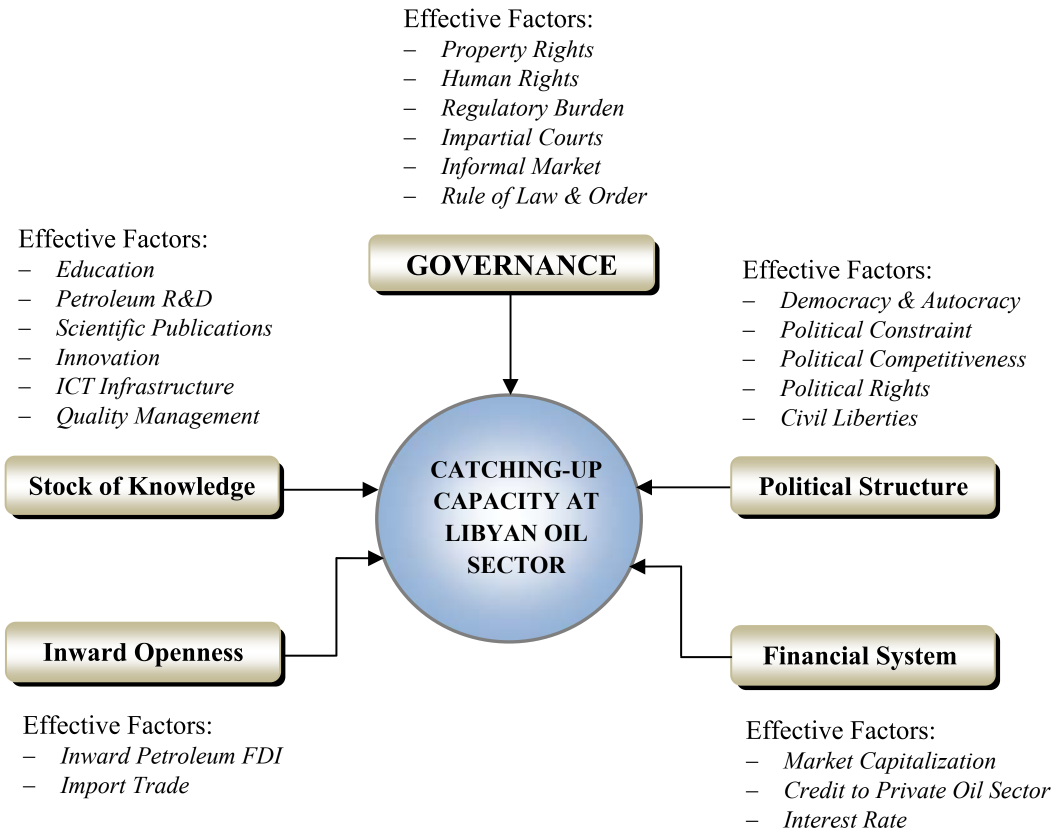


Figure (7.13): Main Pillars of Building Catching-up Capacity at Libyan Oil Sector

Building Catching-up Capacity of Libyan Oil Organizations:

Innovation and capacity building are crucial ingredients for economic growth and sustainable development of nations. This is true for both the industrialized countries that are at the technology frontier and developing countries that need to catch up the technology. Given the large gap of technological achievements between both sides; the developing countries still dependent greatly within the development process on inward technology transfer from the industrialized countries. This drives the developing countries to do more than inward openness for new technologies to flow inside. It entails real continuous efforts by industrial firms along with government policy support to assist acquiring; assimilating and developing the successful technologies (see UN Millennium Project, 2005; UNCTAD, 2005b).

The current technological capabilities of Libyan oil organizations to catching-up the petroleum technology are insufficient. This is attributed particularly, as investigated in this study (see research findings, pp.274-312), to some remarkable causes, namely:

– Poor drivers to petroleum technology development in terms of: 1) funding of R&D activities, 2) significance of technology development for national economy at petroleum organizations and government level, 3) role of Libyan Government towards petroleum technology development, and 4) scientific and technological interactions between the key players in Libyan oil industry.

– Weak enablers to petroleum technology development such as: 1) involvement in R&D activities; 2) self-dependence in doing R&D activities; 3) rate of formulating the technology development process; 4) competency of native technical teams to assimilate the technologies being utilized along various petroleum operations; 5) self-dependence in conducting training and development schemes; 6) absorptive capacity of research community to acquire, absorb and develop technological knowledge; 7) conceptualization capability of research community to build shared vision, formulate technology strategy and explore at the end of the day possible technological opportunities; 8) learning climate towards developing technology; and 9) self-dependence of technical oil services companies in private sector to execute their own work.

– Poor scientific and technical output of Libyan oil sector in terms of: 1) rates of producing research papers and articles, 2) technical bulletins, 3) technical standards, 4) technical directives, 5) scientific books, 6) technical performance reports, 7) applied and granted technological patents, 8) technical copyrights and trademarks, 9) rate of issuing technological know-how licences, and 10) rate of performing technical consultations and industrial designs.

– Strong influence of barriers to technology development at Libyan oil sector as a consequence of impact of the following factors: 1) High barriers to successful R&D projects and technology development at technological competence domain. 2) High barriers at private companies of technical oil services to support action plans of technology development. 3) Effect of globalization on sectoral efforts for technological acquisition in terms of high dependence on foreign technology supplier which reduces accordingly the chance for native suppliers to innovate and create sustainable competitive advantages. 4) Temperate barriers to inward FDI in favour of developing technologies. 5) Sensible influence of organization culture spread at the research community against some valuable principles by which the productivity of personnel can be enhanced.

The technological capabilities building have been always essential for the effective use of petroleum technologies in Libyan oil sector. The development of new capabilities for technological advancements should be considered to both technical and managerial functions within the Libyan oil organizations. The nature of innovation and its required capabilities varies greatly based on the technological complexity of new technology. The building of technological catch-up capacity for Libyan oil organizations can be achieved in the course of four generic stages of petroleum technology development by innovation effort, as shown in the illustrative pyramid of figure 7.14, which was adapted from UNCTAD (2005b).

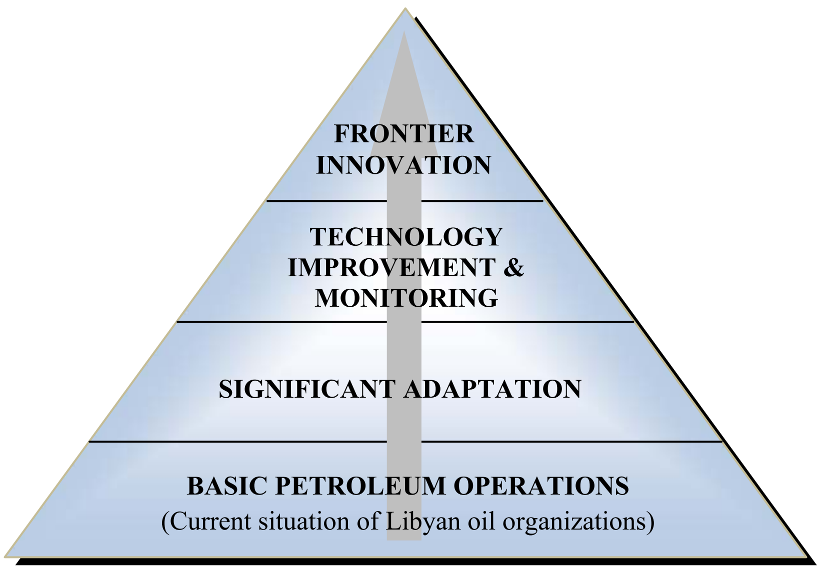


Figure (7.14): Stages of Technology Development by Innovation Effort for Libyan Oil Organizations

The four building stages of technological catching-up that should be considered at Libyan oil organizations along with the technological function of each stage are detailed in table 7.3, which developed based on work done by UNCTAD (2005b) and Arnold et al. (2000).

TECH. FUNCTION	TECHNOLOGICAL CAPACITY
1.Basic Petroleum Operations (Current situation of Libyan	*Type*: Basic Operating Skills and Capabilities
	Aim: Acquisition of basic capabilities to absorb and use existing petroleum technology in various oil & gas production operations.

oil organizations as investigated in this thesis. See the research findings, section 6.5, pp.274-312)	*Key Features*: – Training in essential petroleum technical skills. – Reaching internationally acceptable levels of petroleum production efficiency and performance. – Configuring petroleum products & processes. – Setting up quality management systems. – Instituting supervisory, procurement and inventory management systems. – Establishing in-bound and out-bound logistics.
2.Significant Petroleum Technology Adaptation	*Type*: Technician and Craft Skills and Capabilities
	Aim: Absorption and adaptation of petroleum technology.
	Key Features: – Changing petroleum technology, plant layout, productivity management and quality systems, procurements methods and logistics to adapt petroleum technology to local or export-market needs. – This is based on in-house experimentation and on search as well as interactions with other firms and institutions. – The focus on intensive training efforts.
3.Petroleum Technology Improvement & Monitoring	*Type*: Design & Engineering Capabilities
	Aim: Adaptation into significant petroleum technology improvement and technological learning, with systematic efforts to improve performance of petroleum technologies.
	Key Features: – Improving petroleum technology. – Improving skills to raise productivity and competitiveness. – This is based on own R&D, licensing, interactions with other firms and institutions. – Petroleum technology upgrading through reverse engineering.
4.Frontier Petroleum Innovation	*Type:* Research & Technology Development Capabilities
	Aim: Creating new petroleum technologies as leader or follower.
	Key Features: – Design, develop and test entirely new petroleum technologies.

Table (7.3): Main Stages of Building Catching-up Capacity of Libyan Oil Organizations

The Libyan petroleum organizations are more focused on building up basic operational capabilities (i.e., basic petroleum operations) rather than innovating at the frontier of technological innovation. This is reflected by their low involvement in research and development, poor funding of R&D and their incapability to develop successful petroleum technology (see the research findings, pp.274-312).

For the frontier petroleum innovation stage, the capacity building of Libyan oil organizations is substantially dependent on the capabilities required at the various phases of technology development lifecycle which, as adapted from Martinich (2002), are divided into; innovation phase, chaos phase, standards phase and maturity phase.

Figure 7.15 illustrates typical different phases of technology development lifecycle and their impact on the industry growth of a particular technology.

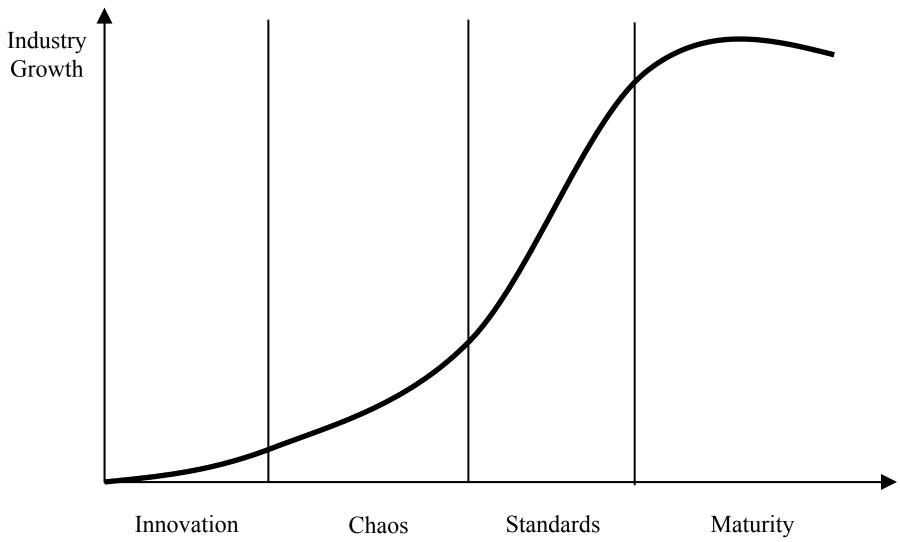


Figure (7.15): Typical Phases of Technology Development Lifecycle

Different phases of petroleum technology development require different management, engineering, marketing, and operations capabilities. The capability framework of frontier petroleum innovation stage includes; *"early phase capabilities"* which comprise both innovation phase and chaos phase, and "*later phase capabilities"* to include standards phase and maturity phase. Table 7.4 details the technological capability framework recommended for Libyan oil organizations.

TECHNOLOGY DEVELOPMENT PHASES	CAPABILITY FRAMEWORK
Innovation Phase KEY FEATURES: – Experimentation and little notice by or interest from either oil organizations or consumers.	*Early Phase Capabilities* CHARACTERISTICS: – Oil organizations need skills and capabilities to cope with fear and chaos in the marketplace. – They need the capability to make the relationship of trust and collaboration with initial customer.
Chaos & Commercialization Phase KEY FEATURES: – The commercial value of the innovation realized by entrepreneurs who try to build a business around the innovation. – Hype, disappointments, fear, suspicion, many entrants, incompatible systems and no standards.	
Standards Phase KEY FEATURES: – The emergence of a standard or dominant design, rapid growth and industry consolidation – Competition shifts to incremental innovations and process improvement.	*Later Phase Capabilities* CHARACTERISTICS: – Oil organizations need skills and capabilities to attack and cannibalize their own markets, and participate in 'creative destruction'. – They need the capability to understand the natural limits of technology and when it is time for the next discontinuous innovation.
Maturity Phase KEY FEATURES: – The technology meets or exceeds customer's needs. – The technology has reached its natural limits. – Competition shifts to customer service and to production and distribution efficiencies. – Process innovation is most important at this phase.	

Table (7.4): Capability Framework of Frontier Innovation Stage for Libyan Oil Organizations.

The organizational absorptive capacity is a dynamic capability that influences the nature and sustainability of oil organization's competitive position (see Zahra and George, 2002). The absorptive capacity is referred to *"the ability of firm to assimilate and reproduce new knowledge gained from external sources"* (Cohen and Levinthal, 1990). Oil organizations being aware of this; try hard to build the technological absorptive capacities of their own in order to generate technological knowledge vital for developing new or improved petroleum technologies.

In the context of building capacity of Libyan oil organizations, the absorptive capacities of teams play a central role in generating technological knowledge and considered consequently an internal drive factor to innovation inside the Libyan oil organization. The team technological capabilities of Libyan oil organizations in terms of absorptive capacity and conceptualization capability of teams (i.e., refers to the capability of research team to build shared vision about research problem, explore possible technological opportunities, formulate R&D strategy, originate research and experimental design, and determine alternatives to solve research problem) are suffering some weakness and needs to be improved (see characteristics of team technological capabilities, p.294).

Therefore, improvement of team's absorptive capacity in Libyan oil organization can be built on investment in the development of individual absorptive capacities through: 1) Building learning capacities which involves development of capabilities to assimilate existing knowledge, 2) Enhancing problem solving skills which represent a capacity to tackle problems and generate new solutions, and 3) Investing directly in building absorptive capacity by advanced technical training and education schemes.

7.4.3 Enhancing Organizational Learning

The need for Libyan oil organizations to become learning organizations and the growing importance of continuing learning and regular updating of individual capacities and qualifications are far urged to include the fundamentals and determinants of organizational learning, as well as mechanisms of enhancing learning in Libyan oil organizations as a key element of this framework.

Organizations incorporated in developing technologies face nowadays a rapidly changing competitive environment which is built, to large extent, in capacity of organizations for learning. That learning process is so important since it helps organizations to acquiring, adapting, and creating knowledge for work success (see Drucker, 1993; Lundvall, 1996).

Learning organization depends absolutely on the skills, approaches and commitment of individuals to learning. Besides, by developing capabilities based on sequence of path-dependent learning, an organization can stay ahead of its imitators and continue to earn superior returns (see Dierickx and Cool, 1989; Teece et al., 1997, Zollo and Winter, 2002).

One way to look at technological knowledge creation, that should be take place in Libyan oil organizations, is through the organizational learning cycle which involves a process of having an experiment, building that in relevant experience, reflecting that experience to new petroleum knowledge and routines, and consolidating that output through execution and auditing (in this regard, see Tidd et al, 2005, Leonard-Barton, 1994). Figure 7.16 shows the elements of organizational learning cycle that should be considered in Libyan oil organizations.

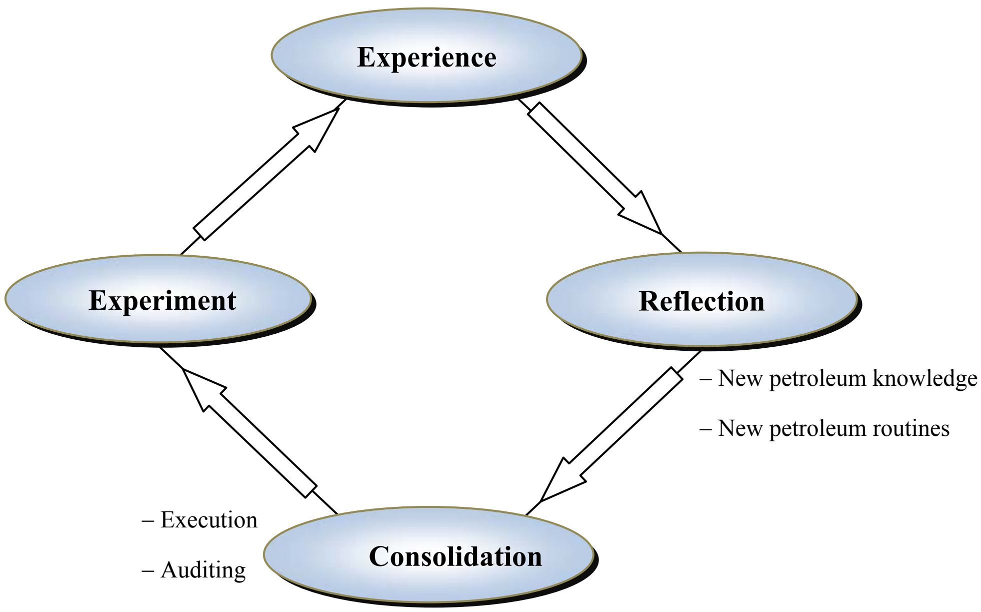


Figure (7.16): Organizational Learning Cycle for Libyan Oil Organizations

Organizational learning in Libyan oil organizations requires in turn integration of both external and internal knowledge for current and future petroleum operations. Therefore, four distinguished activities are critical to achieving learning in these organizations: 1) Problem solving of various work operations. 2) Internal knowledge integration across work functions. 3) Integration of external information flows. 4) Innovation and experimentation to build capacity (see Leonard-Barton, 1994).

Furthermore, learning is considered the most effective way of using knowledge to individual advantage. The opportunities for personal development within Libyan oil organizations range from operations-oriented training courses and typical educational programmes, to distance learning schemes. However, a part of learning in Libyan oil organization is undertaken actually through learning by doing where individuals learn from mistakes and from problem solving feedback (survey data).

The organizational learning is defined by Sitkin et al. (1999) as "*a change in organization's response repertoire"*. In other words, organizational learning involves enhancing an organization's range of possible responses to threats and opportunities. Three points, therefore, are related to this definition, namely: 1) This definition is framed intentionally in general terms to capture changes in beliefs, practices, relationships, or formal structures and processes. 2) The emphasis on repertoire captures the notion that it is not so much that a particular thing must be learned but that some part of the organization's range of available skills and knowledge can be elaborated or modified, whether or not those new capabilities are used. Thus this definition includes strengthening existing skills or routines as well as pruning outdated or inappropriate capabilities. 3) Learning enables the potential for action but that action need not be manifest at the time learning has already occurred. The learning here is in making simpler repertoires more robust and general by understanding more deeply how to apply and adapt them.

Furthermore, the learning in Libyan oil organizations can be embedded in three cross-cutting themes as follows: 1) *Learning content*: Learning can involve changes in action repertories (what the oil organization does) in which the oil organization develops new rules, routines, or pattern of behaviour that respond to environmental and technological changes; or changes in petroleum knowledge repertories (what it knows) in terms of cognitive development rather than action or structural change. 2) *Learning process*: Two types of learning processes are emphasized; the first type is aimed at improving existing routines, while the second is associated with exploring new routines and enhancing organizational adaptability towards avoiding premature clarity and closure when facing ambiguous problems. This is done by experimenting with new strategies, paradigms, practices, and ideas. 3) *Learning Level*: This theme address at what level is learning occurring. It has been found that learning occurred at individual level to generate knowledge in its tacit and codified aspects, and at organization level to focus on changes in organizational structures, processes, and norms (see Sitkin et al., 1999).

All organizations possess their own climate or culture and every one will subject to the influence of the climate in his/her organization. Thus, the right kind of learning climate is no doubt a crucial factor to enhancing organizational learning in Libyan oil organizations. In this regard, the learning climate that surrounds the research community in Libyan oil sector tends to be at a moderate existence degree (see characteristics of work environment, pp.290-293). This entails more efforts to improve that learning climate towards better organizational learning.

As a result, there are two types of climate constituents that are considered conducive to learning or self-development in Libyan oil organizations, namely: 1) *Supportive elements* such as; goals (individual, departmental, organizational) are clearly defined; experimentation is encouraged; mistakes are tolerated (provided learning takes place); individual and cultural differences are respected; a trusting and accepting atmosphere is predominant; collaboration is felt desirable; feelings are considered to be as relevant and as legitimate as ideas and skills; and management systems and relationships are open to inspection and feedback. 2) *Pressure elements* such as; bosses delegate heavily a variety of work problems and activities; managers are encouraged to take leading roles; constructive criticism is encouraged upwards and downwards; competition is accepted as being healthy; open confrontation is a normal relationship; targets are set that are difficult but achievable; managers are placed in positions of ambiguity and uncertainty at times and are told why; as much responsibility is given as early as possible; and managers are asked to change roles, jobs and functions reasonably frequently, i.e. change is a behavioural norm (see Temporal, 1981).

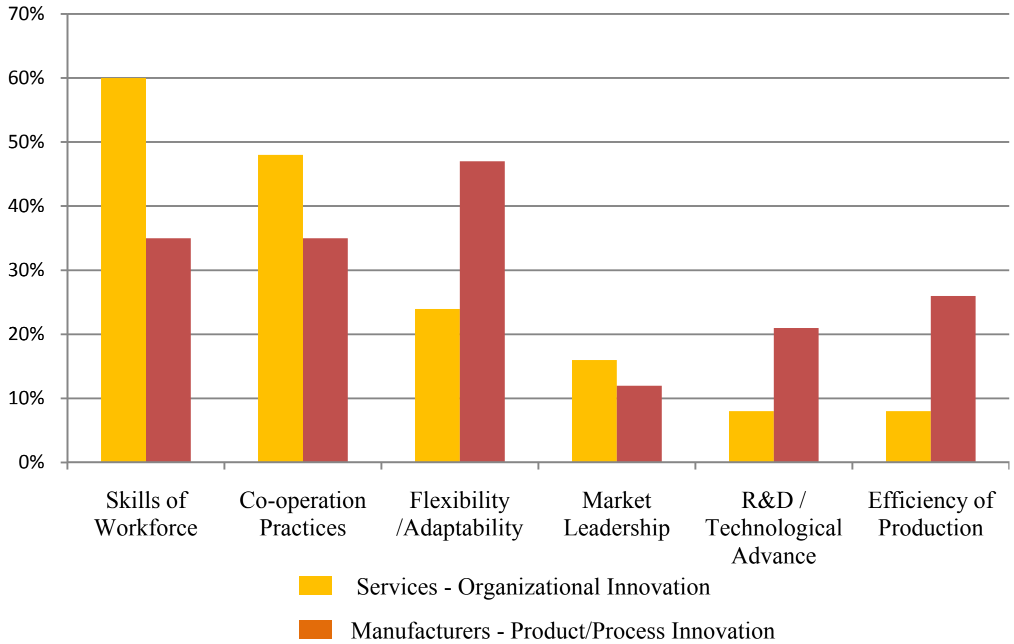
Moreover, a key determinant for relative success or failure in developing petroleum technology in Libyan oil sector is the ability of Libyan oil organizations to learn and manage learning. Therefore, the mechanisms for enhancing organizational learning in Libyan petroleum sector should include: 1) Training and development of employee across all organizational units. 2) Developing deliberate learning processes based on a problem solving cycle. 3) Encouraging experimentation. 4) Challenging the existing work practices. 5) Emphasizing learning from the past activities. 6) Formulating ways of learning from users, suppliers and peers. 7) Supporting integration of internal and external knowledge 8) Reinforcing global outreach through alliances. 9) Embedding learning approach in the organization's management strategy. 10) Establishing a supportive learning climate. 11) Activating incentive systems and promoting organizational values and behavioural norms. 12) Monitoring and auditing the learning process.

7.4.4 Promoting Skills Supply and Attracting Talents

Educated population and highly skilled labour force are key strengths towards growth of Libyan economy. Today only countries that have invested massively in the formation of skills and the R&D infrastructure seem to be able to catch up, while those that have not, fall further behind (Fagerberg and Godinho, 2005).

The role of native skills in driving productivity, as being a measure of the efficiency of Libyan economy is taken for granted. This productivity is driven typically by five factors, which interact in complex ways, namely: 1) Investment in capital (building, machinery, etc). 2) Skills (i.e., investment in people through education, training, and learning). 3) Innovation (i.e., the generation and successful exploitation of new knowledge). 4) Enterprise and entrepreneurship (i.e., willingness to start new businesses, take risks, etc.). 5) Competition between providers of goods and services, (see Tether et al., 2005).

In order to perceiving "strengths at innovation", the European Innbarometer Survey of 2001 shows empirically that services firms with an organizational orientation to innovation placed greater emphasis on the skills of their workforce as being the most significant contributor to innovation process. By contrast, manufacturers with a product and/or process-oriented innovation tended to emphasize at first their flexibility or adaptability to market demands, then, skills of workforce as their major strengths at innovation (see Tether, 2005). This perspective, which is shown in figure 7.17 (p.357) can be used to consider the role of skills supply in both technological and organizational innovation processes at Libyan oil sector.



Source: Adapted from Tether (2005)

Figure (7.17): Main Strengths at Innovation

Furthermore, importance of skill supply to innovation process can be revealed by results of the Third European Community Innovation Survey for 1998-2000 (see Lucking, 2004), as shown in table 7.5. According to this survey, a lack of qualified personnel was regarded a middle ranking factor hampering innovation in Europe in addition to the high costs of innovation which came at the first place.

Factor	EU*	UK	Germany	France	Italy	Netherlands
Innovation Costs too High	1	1	1	1	1	3
Lack of Proper Sources of Finance	2	2	3	2	2	2
Excessive Perceived Economic Risks	3	4	4	3	3	4
Lack of Qualified Personnel	**4**	**5**	**2**	**5**	**4**	**1**
Regulations and Standards	5	3	5	4	5	7
Lack of Customer Responsiveness	6	6	7	7	7	9
Intra-organizational Rigidities	7	8	6	6	9	5
Lack of Information on Markets	8	7	8	8	8	6
Lack of Information on Technologies	9	9	9	9	6	8

* Average value *Source: Adapted from Lucking (2004)*

Table (7.5): Factors Hampering Innovation in Europe between 1998 and 2000

Structure of R&D personnel at Libyan Petroleum Institute (LPI), as being the research community in Libyan oil sector, for average of five years 2003-2007 encompasses: researchers 24.9%, R&D technicians 5.9%, and supportive staff 69.2% (see table 6.25, p.208). Distribution of scientific qualifications of LPI's staff for the same period is as follows: holders of intermediate diploma 13.1%, high diploma holders 3.8%, and bachelors 38.2% which is the largest group, master degree holders 15.4%, doctorate holders 6.1%, and professional qualifications 23.4% (see table 6.26, p.208). Compared to typical distribution of R&D workers in United States of America, for instance in 2003, which has about 59% for bachelors, 28% for masters, 9% for doctorates, and 4% for professional degrees (National Science Board, 2006), the distribution of LPI staff suffers some sort of shortage in bachelors, masters, and doctorates while it has overcapacity in professional qualifications.

Distribution of age versus scientific degree at LPI shows that about 43% of bachelors and 56% of masters are between 35 and 44 years, and about 76% of doctorates are between 45 and 54 years (see table 6.28, p.210). One clear consequence of this age distribution is that a much larger portion of doctorate holders will reach traditional retirement age during the next decade. This alone will have significant effect on supervision and execution of R&D activities if there are no plans to substitute from bachelor and master holders. Therefore, the structure of research community in LPI should be reconfigured in order to bridge the high skills gap through: 1) Promoting holders of bachelors and masters to doctorate degrees, in particular youngest ones. 2) Recruiting native or expatriate doctorate holders. 3) Formulating skill supply strategies that consider all implications of critical mass, distribution of age, and scientific specializations & qualifications required.

The Libyan oil organizations will have accordingly great challenge becoming innovative without a supply of skilled people, who have considerable accumulation of petroleum expertise and years of education, to drive all phases of innovation process. In particular, these organizations will keep seeking more research personnel (specialists, technicians, managers) to strengthen their innovative capacity and maintain their competitive advantage if they are incorporated in continuous technological investments. In this context, the policy makers at both sectoral and organizational levels of Libyan petroleum industry should constitute the appropriate policies to ensure the kind of skills supply to various petroleum operations that are the most in demand through: 1) Improving the education system deliverables in terms of university's graduates and vocational institutes-certified technicians through additional intensive training programmes on frequent basis. 2) Attracting skilled human resources and gifted personnel from local and abroad along with promoting the return of native skilled workers in the diaspora (e.g., up to third of R&D professionals from developing countries reside in the OECD area, see OECD, 2002c).

Polices of improving the education outputs at Libyan oil sector should be closely coordinated with the policies aim at subdue the risk of moving of native people with higher qualifications to multinational oil companies, or migration to other countries in search of proper job opportunities (i.e., "*brain drain*" effect). One way to address this challenge is to developing a deliberate skills demand in Libyan oil sector based on incentive system of wages and convenient work environment, and to consider the Libyan government role as a "skills controller". The Libyan government needs to develop a clear perception of the skills to be in demand in order to speed up skills development in relevant areas. In Singapore, for example, the Ministry of Trade and Industry, the Economic Development Board and the Council for Professional and Technical Education work closely together to monitor future skills needs and drawing on relevant inputs from local and foreign enterprises as well as from education and training institutions (see UNCTAD, 2005b).

As a final point, in the current knowledge society, where highly skilled personnel are more mobilized than ever before as a consequence of globalization impact, the Libyan oil organizations must, therefore, develop polices to build, attract and maintain a critical mass of well-qualified human resources to ensure the success of their missions.

7.5 TURNING IDEAS INTO BUSINESS

7.5.1 Building Innovative Organizations

The innovative organization is that entity which operates a linked set of processes involved in concept generation or market identification, product and process development, production, market introduction and feedback. It is also able to produce innovations serving known markets efficiently and effectively (OECD, 2002a).

The management challenge for Libyan oil organizations nowadays should be focused on how to go about building the kind of organizations in which innovative behaviour can grow. Innovative organization implies more than a structure; it is an integrated set of components which work together to create and reinforce the kind of environment which enables innovation to flourish (see Tidd et al., 2005). The set of components, which are appeared to be linked to building of innovative organizations in Libyan oil sector, are outlined in table 7.6.

COMPONENT	**KEY FEATURES**
Creating shared vision leadership and the will to innovate	– Clearly articulated and shared sense of purpose. – Stretching strategic intent. – Top management commitment.
Appropriate organization structure to cope with the speed and rate of technological change	– Organization design which enables creativity, learning and interaction. – Not to fall into organic, loose, informal environment. – Finding appropriate balance between *organic** and *mechanistic*** organizations for particular contingencies.
Key individuals to innovate	– Key enabling figures such as promoters, champions, information gatekeepers and other roles which energize or facilitate innovation.
Stretching individual training and development internally	– Long-term commitment to education and training to ensure high levels of competence and the skills to learn effectively.
High involvement in innovation for sustainable competitive advantage	– Participation in organization-wide continuous improvement activity.
Effective team working	– Appropriate use of teams (at local, cross-functional and inter-organizational level) to solve problems. – Requires investment in team selection and building, as effective team-building is a critical determinants of project success.
Creative climate	– Positive approach to creative ideas, supported by

	relevant motivation systems. – Involves systematic development of organization structure, communication policies and procedures, reward and recognition systems, training policy, accounting and measurement systems, and deployment of strategy.
External focus on customers and key players	– Internal and external customer orientation. – Extending focus on suppliers, collaborators, competitors, regulators and other players. – Extensive networking.
Extensive communication and networking	– Within and between the organization and outside. – Internally in three directions (upwards, downwards and laterally. – Developing mechanisms for resolving conflicts and improving clarity and frequency of communication across such interfaces are critical to innovation success. Such mechanism include: job rotation and secondment; cross-functional teams and projects; policy-deployment and review session; team briefings and multiple media.
Learning organization	– High levels of involvement within and outside the firm in proactive experimentation, finding and solving problems, communication and sharing of experiences and knowledge capture and dissemination.
* refers to organization which is suited to conditions of rapid change. ** refers to organization which is more suited to stable conditions.	

Table (7.6): Innovative Organization Components for Libyan oil Organizations

The Libyan oil organizations are seemed far from being innovative organizations due to modest capabilities of their teams to: 1) Build shared vision about the research problem to be solved. 2) Search and explore possible technological opportunities. 3) Participate in formulating R&D strategy. 4) Originate research and experimental design. 5) Determine and evaluate alternatives to solve research problem (see team conceptualization capability, p.294)

Furthermore, It is recognized that there are five cultural traits of innovative organizations, namely: 1) Enthusiasm for knowledge by considering encouragement for accumulation of knowledge is a legitimate undertaking; 2) Drive to stay ahead in knowledge which means staying knowledgeable about the latest developments in technology; 3) Tight coupling of complimentary skill sets which refers to simultaneous attention to both developing deep reservoirs of knowledge and skill in special capabilities and having a plan to diminish the boundaries between disciplines; 4) Alteration in activities which reflects the comprehension of the fact that activities are never completely perfect; and 5) Higher order teaming to continual self-examination to discover insights within one activity that may be transferred to other activities within the firm (see Narayanan, 2001).

The characteristics of firms that demonstrate best practice in the field of innovation should be of much benefit for the Libyan oil organizations to consider towards technological development. These characteristics include: 1) Propensity for risk taking and tolerance for ambiguity. 2) Proactive and anticipate rather than react to change. 3) Top management commitment. 4) Customer and market orientation. 5) High degree of employee motivation and commitment. 6) Flexible team-based work structure. 7) Effective horizontal communication mechanism. 8) Emphasis on technical skills development. 9) Ability to relate technological skills to strategic intent. 10) Continuous and intensive organizational collaboration. 11) Openness to sharing information.12) Developing reward system that recognizes entrepreneurial behaviour. 13) Entering segments in which the firm can win (see Harrison and Samson, 2002).

7.5.2 Boosting Technological Entrepreneurship

Entrepreneurship is the creation of an innovative economic organization for the purpose of gain or growth under conditions of risk and uncertainty. The Libyan oil sector has a lack of entrepreneurship activities, as being investigated in this study (see table 6.21, p.206). This dearth is considered one of the key barriers to technology development. Entrepreneurship scarcity prevents native individuals and entrepreneurs from establishing their own petroleum investments, under many aspects of risk, with the aim of transferring the innovative endeavours they adopt into physical products and service that would sustain various petroleum tasks in Libyan oil sector. In order for entrepreneurship to flourish in Libyan oil sector three main conditions should be exist: 1) no barriers to establish a business venture, 2) lack of restrictions to be creative and innovative within that enterprise, and 2) economic progress and positive business environment that offer that venture the opportunity to succeed.

Entrepreneurial work comprises some vital dimensions. The multidimensional approach of successful entrepreneurship for production/service business that should be highly considered in new Libyan oil enterprises, as rooted in studies performed by Dollinger (1999) and Kuratko & Hodgetts (2007), is shown in figure 7.18.

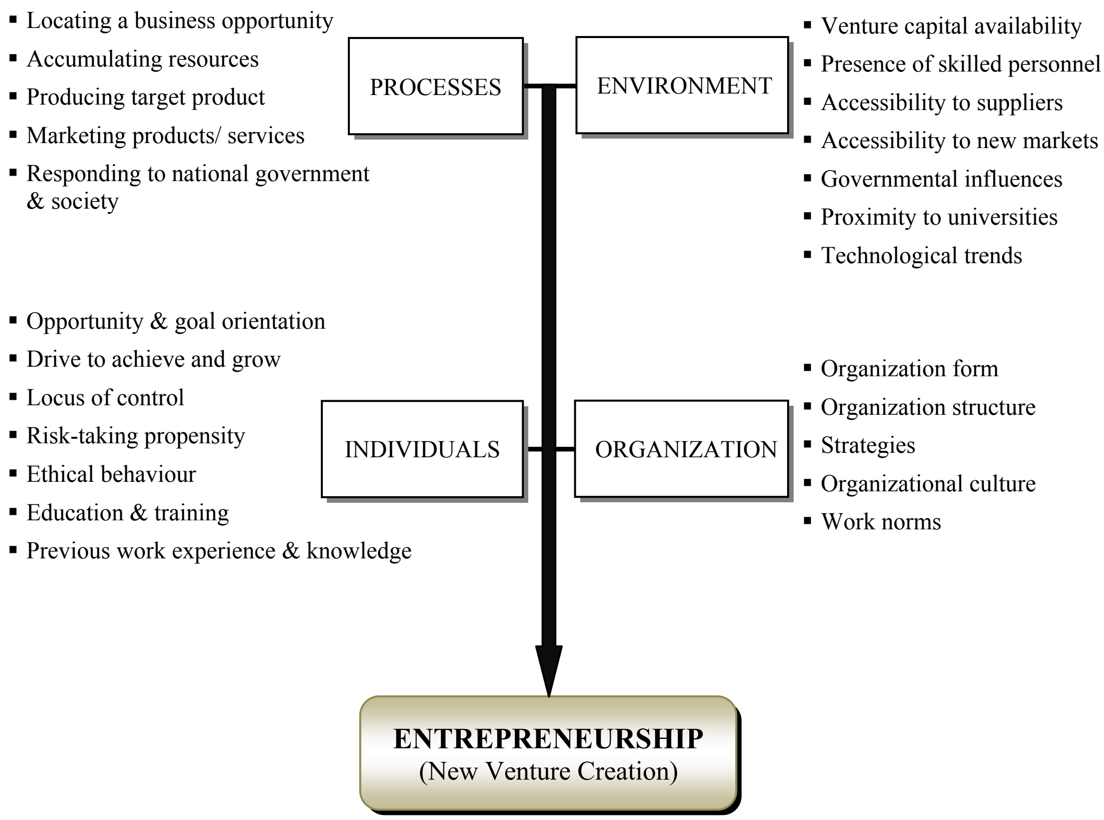


Figure (7.18): Main Dimensions of Successful Entrepreneurship for New Libyan Oil Enterprises

The fundamental dimensions for successful entrepreneurial in new petroleum ventures are as follows:

– *Processes*: The entrepreneurs build their businesses from the resources and capabilities they currently possess or can realistically acquire (i.e., accumulation of resources). They are using resources that are rare, valuable, hard to copy, and have no good substitutes (*Resource-based Theory*) in positive business conditions in order to provide sustainable competitive advantage. In simple language, what is known to all is an advantage to none. So you can get smarter without getting richer if the knowledge you possess lacks any of the four characteristics (rare, valuable, hard to copy, no substitutes). Locating a business opportunity, producing related product, marketing the products or services, and responding to national government and society are all issues which should be built into the entrepreneurship strategy.

– *Individuals*: The role that individuals play in entrepreneurship is undeniable. Each person's characteristics contribute to or detract from his/her abilities to be an entrepreneur. Personal experience, knowledge, education, and training are the accumulated human resources that founder(s) contributes to the enterprise. One clear pattern among successful entrepreneurs, as being individuals, is their focus on opportunity rather than on resources, structure, or strategy. They are goal oriented in their pursuit of opportunities. The risk profile of the entrepreneur determines the initial configuration of the venture. Growth-minded entrepreneurs do everything possible to get the odds in their favour, and they often avoid taking unnecessary risks. One of the most important responsibilities of the entrepreneur is the establishment of business ethical behaviour which helps build and sustain trust and confidence with customer, investor, and partner, and affects accordingly the integrity and reputation of the firm. Locus of control is a trait often associated with entrepreneurship belief, which means efforts always breed outcomes. This attribute is consistent with a high-achievement motivational drive, the desire to take personal responsibility, and self-confidence.

– *Environment*: The environment poses both opportunities and threats for new petroleum venture creation. The opportunities come mostly in terms of resources – money, people, and technology. The threats, or constraints, imposed by the environment are those inherent in any competitive marketplace. To overcome or subdue these threats the entrepreneur should develop strategies that exploit the venture's resources. The key elements that constitute the environment are the national government and politics, the economy, technology, socio-demographics, and the ecosystem. Since the environment is characterized by change, uncertainty, and complexity, entrepreneurs should continuously monitor events and trends and make adjustment to their organizational structure and strategies.

– *Organization*: The result of nearly all entrepreneurial ventures is the creation of new organization. The organization has a form and structure. It has strategies that enable it to penetrate or create market (competitive entry wedges) and protect its position (isolating mechanism). It possesses resources and work norms that add value to its customers. The organization can have a culture that stimulates the performance and supports the excellence.

7.5.3 Commercializing Innovative Efforts

Commercialization of innovative endeavourers is a central joint of R&D outputs, inventions and entrepreneurship. It comprises activities and processes that link economic value creation to economic value realization. A commercialization process may include some elements ranging from initiatives of market thinking to key commercialization projects such as knowledge/technology parks, incubators, spin-offs, corporate venturing, venture capital fund and patenting system. In various commercialization cases, different players are integrated either all together or alone such as the university-industry collaboration, non-firm organizations, and private companies.

Knowledge/technology parks and incubators are special physical environments for the creation of economic value through the development, application, and transfer of knowledge and the creation of new enterprises. The parks are triggered by the increasingly large role played by knowledge generated by R&D in industry and other value-added activities. Where successful, the parks become a powerful instrument of economic and social development and can profoundly influence urban planning (see Gibbs, 1985; Bugliarello, 1996).

Technology parks include a vast spectrum of commercial innovation activities that overlap the interaction of research and business activities. Figure 7.19 (p.366) illustrates the type of activities that technology parks encompass as adapted from Victorian Government (2001).

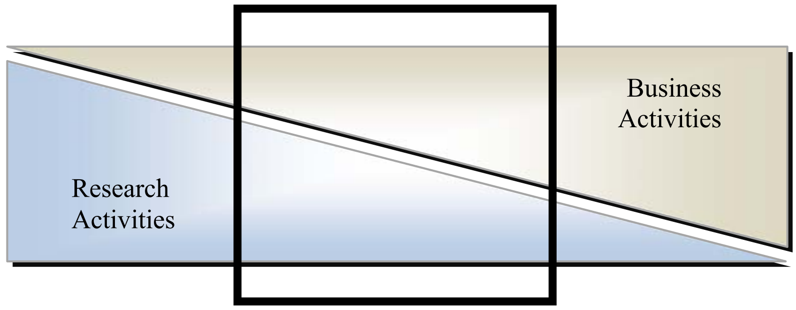


Figure (7.19): Typical Interaction of Research and Business Activities in Technology Parks

For Libyan oil industry, commercialization of local petroleum research performed by Libyan petroleum institute, Libyan oil firms, and some related local universities and research institutes is suffering some difficulties, namely: 1) low level of native research output (i.e., significance & quality), 2) weak involvement in R&D activities, 3) limited R&D infrastructure, 4) poor scientific and technical output of Libya oil industry, 5) weak local interactions between Libyan oil industry, universities, and research institutes that can impede any kind of commercial integration, 6) poor funding of local R&D, and 7) management problem within Libyan oil industry.

The mechanisms to stimulating the research activities in Libyan oil sector (see figure 7.13, p.341) along with establishing a project of petroleum technology park, in which concentration of new innovative enterprises located for the purpose of creating profitable value through transferring the local petroleum research into physical end products and process, are very crucial elements to spur technological development in Libyan oil industry towards solving problems of technical operations and enhance growth of national economy.

In this context, Libyan oil industry, local universities & research institutes and foreign oil companies can play significant role in establishing the petroleum technology parks. The role of national government in this regard is to facilitate all activities related to establishing and success of the park. Figure 7.20 (p.367) demonstrates a conceptual diagram of key actors and their roles towards the presumed petroleum Technology Park in Libyan oil sector.

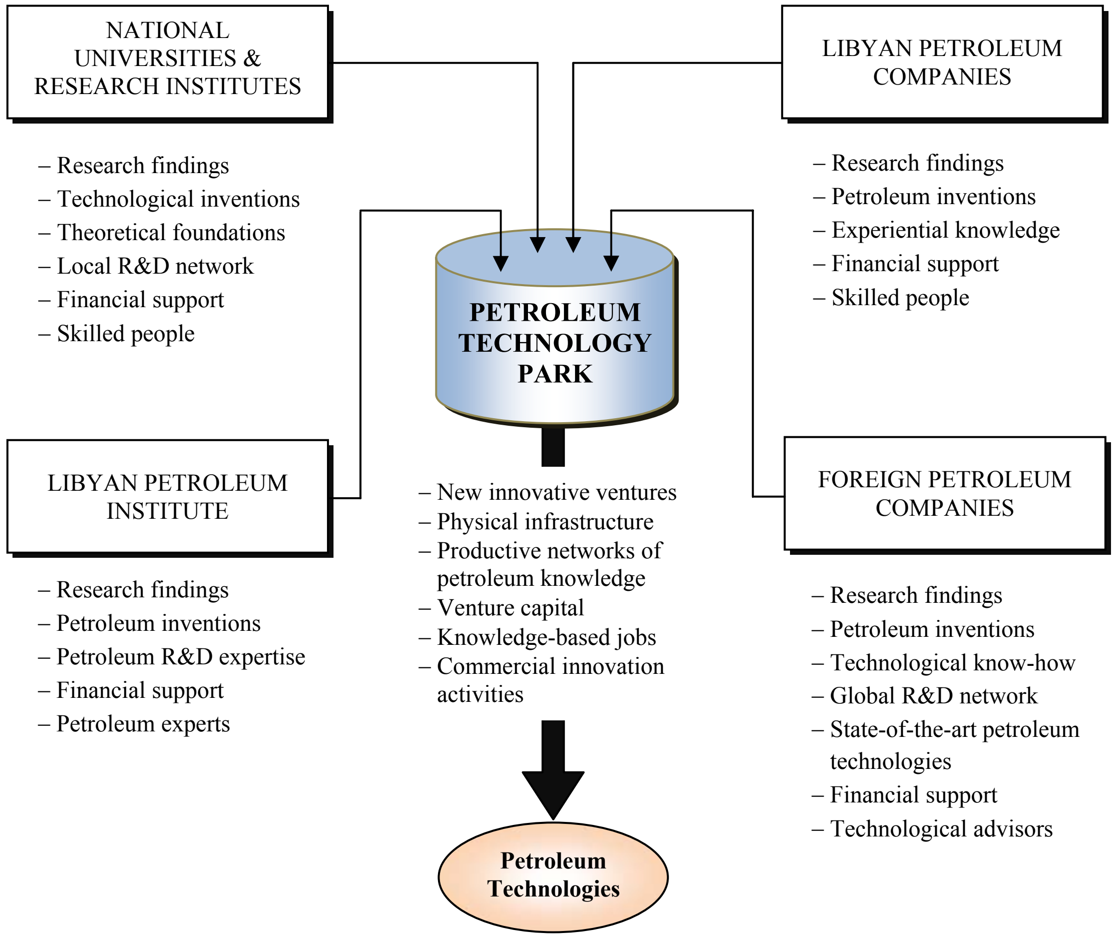


Figure (7.20): Main Characteristics of Presumed Technology Park in Libyan Oil Sector

Presumed Technology Park in Libyan oil sector can play significant role towards technological development through its prominent characteristics, namely: 1) it will house new petroleum ventures of local R&D organizations and national & foreign petroleum firms from both public & private sectors, 2) organizations will be attracted to the site because of the benefits they will gain from their access to the productive networks of petroleum knowledge existing among the park infrastructure. This infrastructure is what the technology park builds its reputation on and uses to attract and stimulate new commercial activities, 3) new innovative ventures will benefit from physical facilities of technology park and availability of financial support in terms of venture capitals. 4) national universities and research institutes related to Libyan petroleum industry can contribute to the technology park through petroleum research findings, new technological inventions, theoretical underpinning to technological endeavours, share of local R&D network, financial support and supply of skilled researchers, 5) Libyan Petroleum Institute can provide the technology park with petroleum research findings, new technological inventions, petroleum R&D expertise, financial support and experts supply, 6) Libyan petroleum companies in both public and private sectors can supply the park with petroleum research findings, new technological inventions, experiential knowledge accumulated from day-to-day activities of problem solving, financial support and supply of skilled personnel, 7) foreign petroleum companies have very important role to play towards the prosperity of the technology park, within their contributions to programmes of national technological development. Their role can be accomplished in terms of research findings supply; technological inventions; technological know-how; access to global petroleum R&D networks; access to state-of-the-art petroleum technologies; financial support and supply of technological advisors.

Moreover, the petroleum technology park will promote the economic development and competitiveness of Libyan oil sector by: 1) creating new business opportunities and adding value to mature oil companies. 2) Fostering entrepreneurship and incubating new innovative ventures. 3) Generating knowledge-based jobs. 4) Building attractive spaces for the emerging knowledge workers. 5) Enhancing the synergy between local universities, Libyan oil industry and foreign oil companies

New technology-based companies (start-ups/spin-off ventures) to be created in the petroleum park is an effective tool to transferring technology that originated either in national universities, public funded- R&D laboratory, or Libyan petroleum firms in both public and private sectors. In this sense, four principle entities are often involved in the spin-off process: 1) *Technology originator*: The person or organization that brings the R&D from basic concepts through the stages of the innovation development process to the point at which the transfer of technology can bring. 2) *Entrepreneur*: The entrepreneurial individual or team who takes the technology created by the originator and attempts to create a new business venture. 3) *R&D organization*: the entity that often is represented in the spin-off process by its technology licensing office. 4) *Venture Investor*: Generally a venture capital organization that provides funding for the new venture in return for partial equity ownership in the new company (see Rogers and Steffensen, 1999).

Large corporations are frequently found as spin-off parents, either as a result of restructuring activities, or as a result of internal entrepreneurial activities. The spinning-off of innovative ideas that fall outside the core business of the large parent organization can create new business opportunities that otherwise may not have been commercialized. A private corporation may also spin off ideas when it wants to downsize its operations. To do this without causing increased unemployment and a bad reputation can be reasons why large corporations sometimes encourage spin-offs from their organization (see Wallin and Dahlstrand, 2006).

Universities' spin-off companies are considered the most tangible form of commercialization and implementation of the entrepreneurial vision of university research. The increasing interest of developed countries in academic spin-offs reveals the significance of research knowledge as a strategic resource for economic development and sustainable competitive advantages of firms. An example of single research university's impact on the economy by means of spin-offs is provided by the Massachusetts Institute of Technology (MIT). In 1997, the 4000 MIT-related spin-off firms employed at least 1.1 million people and generated US$232 billion in worldwide sales (see Rogers and Steffensen, 1999).

7.6 DRIVING INNOVATION BUSINESS

7.6.1 Enabling Innovation Culture

Culture is the shared and relatively enduring patterns of basic values, beliefs, and assumptions in an organization. It is the collection of norms, behaviours, and values that guide action without managerial intervention. Culture is usually the most difficult organizational asset to evaluate, but it is also the most powerful as provides implicit guidance for desired behaviour; it frames right and wrong, and highlights the things for which individuals are most admired and recognized.

Organizational culture, which spreads within the research community of Libyan oil sector, is of negative features such as; time is not much important in daily work life of Libyans, no real challenging work being seriously considered, and loyalty before capability when recruiting or assigning work leaders of all levels (see organization culture in research community, pp.291-292). This negative organizational culture can highly impact the behaviour of research personnel and create a climate of frustration if no corrective actions considered to changing these beliefs.

In identifying and trying to influence organizational culture in Libyan oil sector, managers of Libyan oil organizations should be aware of the following areas in which culture can be recognized and improved: 1) *Vocabulary*: Words and phrases typically expressing important values and ideas. 2) *Methodology*: The established norms by which the Libyan oil organization gets things done. For example, does the organization use internal task forces or external consultants? 3) *Rules of conduct*: The unwritten do's and don'ts that guide day-to-day behaviour from etiquette to actions of decision making. 4) *Values*: Such as the belief in being the best, the belief in the importance of human resources, the belief in superior quality and service, the belief in importance of innovative efforts to the organization's competitive advantage, etc. 5) *Rituals*: Such as types of announcements, holiday parties, or the way people introduced. 6) *Myths and stories*: Who are the heroes? Are the stars acknowledged to be those making positive contributions? Is good or foolish to work hard and long hours? (See Shenhar & Adler, 1996)

Culture is typically considered a potential control system that can help or hinder the execution of business strategies and promote or retard innovation undertakings in Libyan oil sector. Hence, it is important for managers in Libyan oil organizations to align culture with business strategies and critical tasks to ensure that social control system within their organizations promotes the execution of these strategies. Four mechanisms are commonly used by strong culture organizations to generate commitment and management through social control. These mechanisms will be of much benefit if to be adopted by Libyan oil organizations as the primary levers to develop culture as social control system control and improve organizational culture, namely: 1) System of participation that promotes choice and lead people in the organization to feel committed. 2) Management actions that set goals, focus attention, and help people interpret events in ways that emphasize their intrinsic importance. 3) Consistent information from valued others signalling what is and what is not important. 4) Comprehensive reward systems that are seen as fair and emphasize recognize, approval, and individual and collective contributions (see O'Reilly, 1999).

Moreover, it is basically recognized that innovation is an outcome which has occurred only because something has changed. This means that there are two components that underlie the innovation: 1) *Creativity*: The generation of a new idea, and 2) *Implementation*: The actual introduction of the change. Innovation occurs only when both components are present. Thus to promote innovation in Libyan oil organizations requires that managers stimulate new ideas and put these ideas into practice. In this regard, there are four culture norms that are significantly related to innovation and they can be useful for Libyan oil organizations. Two of them for stimulating creativity: 1) Support for risk taking and change. 2) A tolerance of inevitable mistakes and treating them as learning experience. The other two norms are associated with implementation: 1) Effective teamwork and group functioning. 2) An emphasis on speed and urgency (see Caldwell and O'Reilly, 2003).

In conclusion, culture as an organizational asset is an important tool for supporting strategic goals and motivating the human resources in Libyan oil sector. Developing an organizational culture, that embodies norms of creativity and change and in which value of innovation as a strategic competitive means is fully realized and appreciated, is the most effective premise for local organizational growth in Libyan oil sector.

7.6.2 Strengthening Institutional Set-up

Cognition, actions and interactions of agents within innovation systems are shaped by institutional framework which include norms, routines, common habits, established practices, rules, laws, standards, and so on. The framework constitute institutions that may range from those that bind or impose enforcements on agents to those that are created by the interaction among agents such as contracts; from more binding to less binding; from formal to informal such as patent laws or specific regulations versus traditions and conventions. Many institutions are national such as the patent system, while others are specific to sectoral systems such as sectoral labour markets or sector-specific financial institutions (see Malerba, 2004, 2005).

The Libyan Government can play an essential role in relation to supporting innovation and nations' competitive positions in the global arena. This can be through developing a well-purposeful institutional framework that constitutes a set of vital regulations and policies to ensure: 1) Creating a stable political system towards permitting economic growth. 2) Establishing the good governance, which is a crucial element of catching-up, to protect the property rights and human rights, subdue the regulatory burden, strengthen the justice system, combat corruption, and enforce rule of law & order. 3) Enhancing competition and preventing monopolies that can result in under-innovation and protecting the society against possible abuse by firms. 4) Facilitating strategic orientation and building innovative capabilities. 5) Developing strong research organizations to foster proactive involvement in the acquisition, development and transfer of technology. 6) Supporting initiatives of adoption, adaptation, and diffusion of technology and related know-how. 7) Developing strong financial institutions capable of supporting sustainable technical progress. 8) Establishing the educational and training systems capable to deliver the kind of skills in demand. 9) Spurring creativity and entrepreneurship. 10) Protection of intellectual property rights. 11) Enhancing local interactions of university-government-industry. 12) Developing strategic alliances with compatible countries to enhance technological progress and strengthen partnership. 13) Inflow of foreign direct investment for technological development. 14) Positive technology knock-on effect to ecosystem and society.

7.7 MONITORING INNOVATION PERFORMANCE

7.7.1 Setting up Sectoral System of Excellence

Monitoring and controlling the innovation performance is a management control function that can be performed either at organization or sector level of Libyan oil industry. This control process entails setting up sectoral system of excellence for innovative performance of Libyan oil organizations in order to be considered as the basis for the measurement and assessment processes.

In Libyan oil sector, there is no yet a practical tool to control the innovation performance of oil organizations. This is owing to: I) Lack of awareness at Libyan policy makers of all levels about significance of national technological innovations to solve problems of petroleum operations and enhance national economy (see significance of technology development, p.284). II) Weak involvement of Libyan oil organizations in R&D has led to lack of local innovation assessment (see involvement in R&D, p.274). III) Existence of high barriers to R&D and technology development in Libyan oil sector hinders the assessment process of local innovation performance (see barriers to successful R&D projects and technology development, pp.284-285). IV) Weak role played by Libyan government towards technology development discourages innovation performance control in Libyan oil sector (see role of Government towards technology development, p.286).

Total quality management (TQM), which is relatively new management approach, has evolved from the concept of Statistical Quality Control (SQC) to a more holistic approach nowadays. The Excellence model, developed in 1991 by the European Foundation of Quality Management (EFQM), reflects the latest step in the evolution of quality management theories.

The EFQM excellence model is a non-prescriptive framework for continuous quality improvement that can be used by any kind of organizations, regardless of sector, size, structure, or maturity. The excellence model is now widely recognized across Europe as a practical management control tool to help organizations measuring where they are on the path of excellence, helping them understand the gaps, and then stimulating solutions. The model is applied and monitored through self-assessment and can be administered internally (see EFQM, 2003a).

In this regard, the EFQM excellence model can be considered consequently the appropriate sectoral system of excellence for measurement and assessment of innovation performance in Libyan oil organizations. The best strategy for using this model as a control tool in Libyan oil sector is through "*adaptation*" rather than "*adoption*". Hence, before applying the EFQM excellence model for improving petroleum innovation in Libyan oil sector it is recommended to using all existing knowledge and experience to revise the model so that it better fits with the given context and scope of practices. This is called adaptation (see Dahlgaard-Park, 2008).

The adaptation of the EFQM excellence model to fit the assessment of innovation performance in Libyan oil sector entails originally establishing a sectoral steering committee of elite experts capable to: 1) Setting up and managing the adaptation process of the excellence model to cover all technological innovation aspects and management specifics which have to be monitored and controlled. 2) Configuring the structure and content of adapted model in order to define sub-criteria, measures of excellence, relevant appraisal questions, and system of scoring. 3) Supervising, corroborating and validating the assessment processes that will be taken place by the Libyan oil organizations involved in technological innovation, and 4) Benchmarking innovation performance of all participated organizations towards identifying technological strengthens and weaknesses.

The EFQM excellence model, as shown in figure 7.21, comprises nine criteria, five are Enablers and four are Results. The Enablers criteria cover what an organization does. The Results criteria cover what an organization achieves. Enablers cause Results. The nine criteria are sub-divided into a total of thirty three sub-criteria. Each sub-criterion poses a number of questions that should be considered in the course of an assessment (see Dahlgaard-Park, 2008).

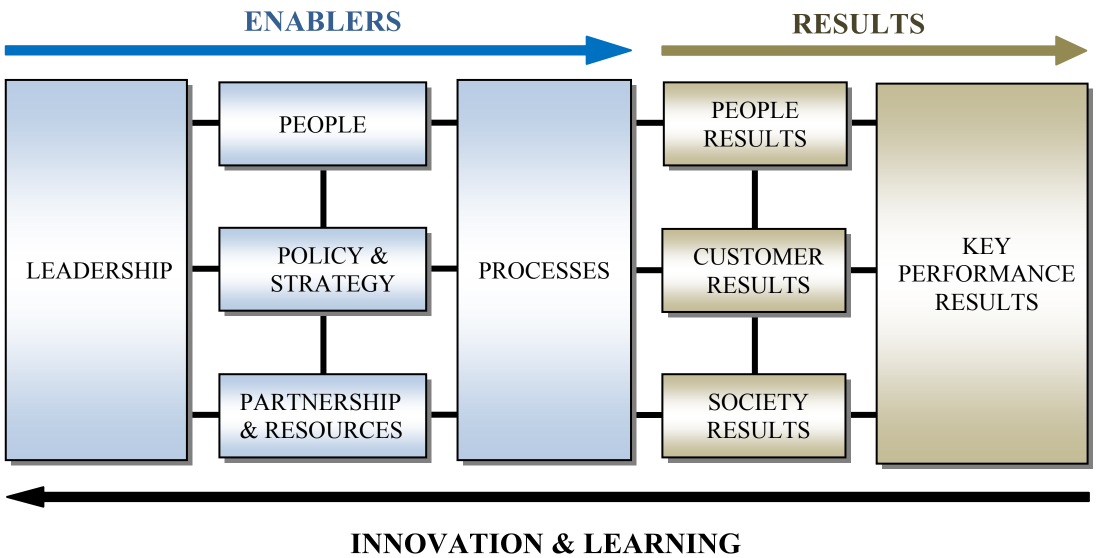


Figure (7.21): The EFQM Model of Excellence

The EFQM excellence model can be considered as a holistic and integrative approach, where strategic, managerial and operational control processes are integrated in the model as interrelated enablers. The strategic planning is explicitly incorporated in the criterion of Policy & Strategy, the operational control is explicitly incorporated in the Process criterion, and the management control is embedded in all other four Enablers criteria.

The basic framework of the EFQM excellence model consists of eight elements which are the fundamental concepts of excellence. These are concepts that Libyan oil organizations aspiring to become excellent need to consider and put in place in ways relevant to them. The eight concepts are: 1) Leadership and constancy of purpose (e.g., how well do managers in Libyan oil organization lead?). 2) People development and involvement (e.g., how effectively are people in Libyan oil organization managed and involved?). 3) Continuous learning feedback that promotes innovation and improvement. 4) Partnership and resources development (e.g., do Libyan oil organization have what it need and make best use of it?). 5) Management by processes and facts (e.g., how do Libyan oil organization perform things and ensure customer focus before and after contact?). 6) Corporate social responsibility (e.g., what is the effect of Libyan oil organization on the outside world?). 7) Results orientation including key performance outcomes and sustainable development (e.g., is Libyan oil organization achieving as much as it could?). 8) Customer focus including client collaboration and the measurement of customer satisfaction (see EFQM, 2003b; Medhurst and Richards, 2007). In other words, the model is based on the premise that: "*Excellent results with respect to performance, customer, people and society are achieved through leadership driving policy and strategy that is delivered through people, partnerships and resources, and processes*" (Dahlgaard-Park, 2008).

The cause and effect relationships in terms of the linkage between the various Enabler criteria and the Results criteria are clearly grounded in ideas about the generation, processing, and feedback mechanisms of information. Through the Enabler criteria, information is expected to be generated and processed. The Results criteria in terms of people and customer satisfaction, impact on society as well as business results are expected to be utilized as feed forward loops in an ongoing process, and in this way, it is assumed to increase learning and improvement activities by reassessing goals, strategies and standards in the Enabler criteria.

An integral part to EFQM excellence model is the RADAR logic, which should help the Libyan oil organizations determine how excellently they are carrying out their various approaches. The RADAR logic is an acronym for Results-Approach-Deployment-Assessment-Review. For Libyan oil sector, the RADAR logic states that the Libyan oil organization needs to: 1) Determine the *Results* it is aiming for as part of its policy and strategy making process. The results cover the performance of the organization, both financially and operationally. 2) Plan and develop an integrated set of sound *Approaches* to deliver the required results both now and later. 3) *Deploy* the approaches in a systematic way to ensure full implementation. 4) *Assess* and *Review* how well the approaches are working based on monitoring and analysis of the results achieved and ongoing learning activities. Moreover, identify, prioritise and implement improvements where necessary (see Medhurst and Richards, 2007).

7.7.2 Auditing and Improving Technological Performance

Auditing is a useful tool aims at evaluating the existing status or performance of a particular organization. Technology audit is an analysis performed to identify the strengths and weaknesses of the technological assets of an organization. Its aim is to assess the firm's position in technology in relation to its competitors and the state of the art developments.

For Libyan oil organizations involved in technological developments, technology audit should provide answers to the following questions: 1) What are petroleum technologies and know-how on which organization's business depends? 2) How does the organization's technology position compare to its petroleum competitors? Is it a leader, a follower, or a laggard? 3) What is the technology life-cycle position on which the organization depends? 4) Where is the organization's strength? Is it in petroleum product technology or technologies of production & processing operations or a combination of technologies? 5) Is the organization effectively protecting its distinctive core technologies? 6) What emerging or developing technologies, inside or outside the organization, could affect its technological position or its market position? 7) What is the organization's technology value that can be added to the customers? Is there a big technology gap that gives the organization an advantage in petroleum knowledge as well as in pricing its products? 8) Does the organization have a systematic procedure and a supporting organizational structure that allows optimal exploitation of its technologies internally and externally? 9) Does the organization have the technological assets that it can share with other oil organization? Some of the ideas that need to explore include selling technology that is no longer used by the organization, creating joint ventures to exploit the organization's strength, and transferring technology to another company or country?

10) What social, political, or environmental factors might impede the natural progress of the organization's technology strategy?

A framework of technology effectiveness audit has been adapted from Garcia-Arreola (1996), as cited in Khalil (2000), in order to be used by Libyan oil organizations implicated in technological development activities for the aim of: 1) determining current technological status of the organization, 2) stressing areas of key opportunities for continuous improvement, 3) determining the organization's strong capabilities and weaknesses, 4) benchmarking with peers in petroleum technology sector, 5) measuring the progress achieved and the effectiveness of implementation, and 6) using as a self-assessment instrument leading to proper technology planning.

The framework of technology effectiveness audit for Libyan oil organizations includes the following six categories: 1) *Technological environment*: Elements of successful business environment to be examined include leadership commitment and involvement, strategies adopted, organizational structure, technology structure, and human resource management. 2) *Technologies categorization*: It is important to evaluate the oil organization's level of knowledge and appreciation of its own technologies, state-of-the-art technologies, and emerging technologies. 3) *Markets & competitors*: A profound understanding of the environment in which the oil organization competes is critical for technology management. Business decisions in this regard include relationship with suppliers and customers, pricing, the selection of distribution channels, product positioning, and so on. 4) *Innovation process*: the ability of the oil organization to bring an innovation to the market in the shortest possible time is as important as the innovation itself. Business decisions in this area include ideas generation, technology generators, product launching time, and so on. 5) *Value-added functions*: Petroleum technology is brought to the market through value-added functions such as R&D, manufacturing, sales and distribution. Evaluation of business decisions in this area includes review of team performance, research portfolio justification, development process improvement, and environmental concern in terms of producing environment-friendly products. 6) *Acquisition and exploitation of technology*: The effective adoption of petroleum technology requires that knowledge flow from source to receiver. Technology effectiveness depends on how successfully this process is performed. Business decisions for acquisition and exploitation of petroleum technology include review of acquisition methods, capital investment, technology transfer process, technology exploitation methods, and means of technology protection.

Technology audit framework for Libyan oil organizations is depicted in figure 7.22.

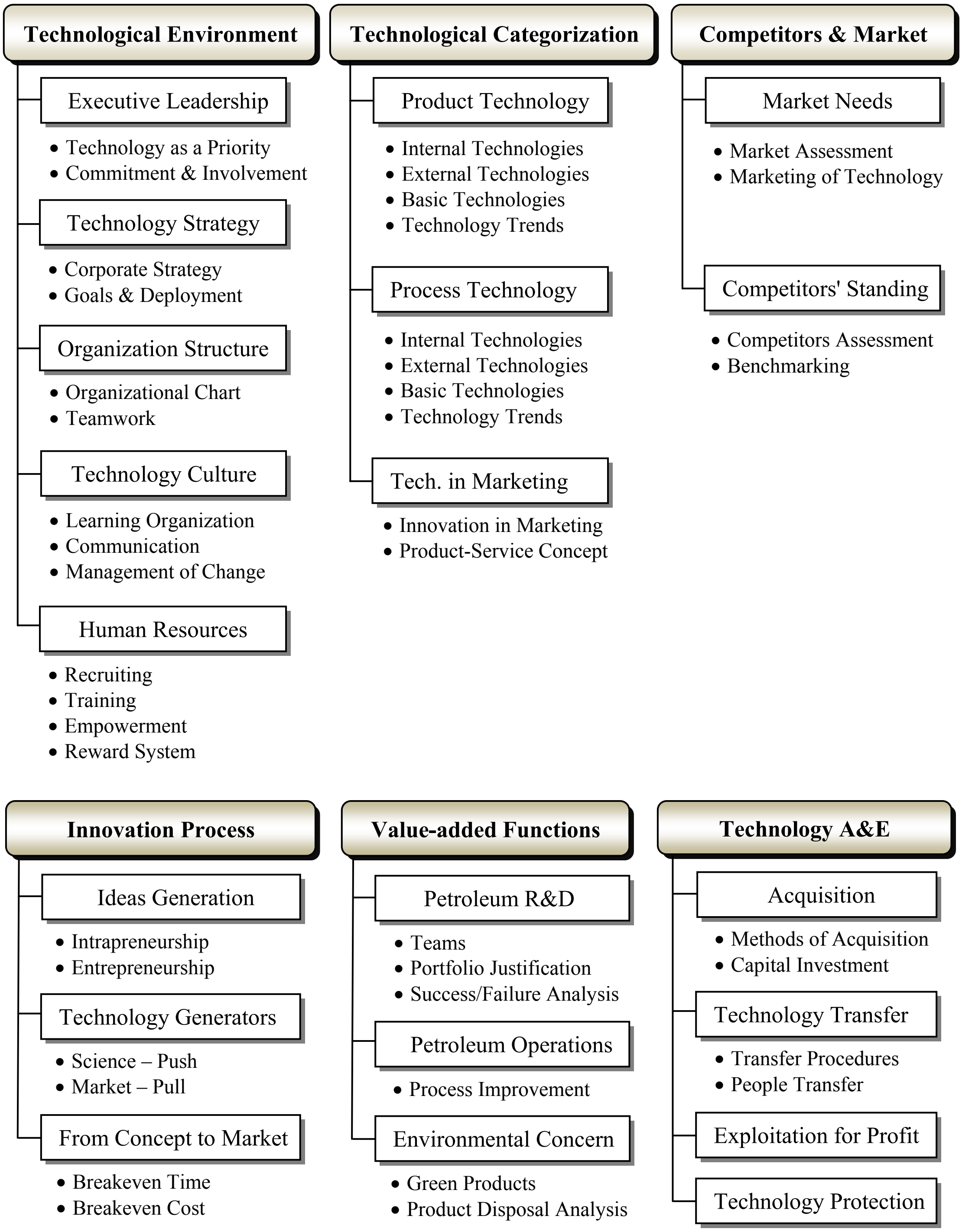


Figure (7.22): Framework of Technology Effectiveness Audit for Libyan Oil Organizations

Chapter Eight

CONCLUSIONS AND RECOMMENDATIONS

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

- Technological change and innovation are the major drives for the economic growth of nations. Innovation and technology are principally needed to transform countries from reliance on the exploitation of natural resources to knowledge-based economies which are directly based on the production, distribution and use of knowledge and information. The key source of sustainable competitive advantage within an industry in the knowledge-based economy is how a firm creates and shares knowledge for targeting profitability. Despite the increasing globalization of technology, the involvement of developing countries in producing new technologies and innovations is almost negligible. The production of knowledge is mainly concentrated in industrialized countries.

- Productivity and income of organizations hinge increasingly on their ability to rapidly build up technological capacity for competitiveness. This places capacity building at the core of technological development systems. The rate of accumulation of technological capabilities and nature of learning patterns both have an inherent tendency to translate into economic prosperity gaps across developing countries comparing to their developed counterparts. Narrowing these gaps requires a fast track catching-up efforts of various kinds. Pivotal among these undertakings is a deliberate building of technological capacity within a framework of technology management.

- Traditional innovation systems such as national innovation system and sectoral innovation system are essentially *structure-based view*. These systems focus on demonstrating the system structure – including knowledge, actors, interactions and institutional set-up – rather than paying attention to elaborate the innovation activities (causes and determinants) in terms of *activity-based view.* The role of these innovation frameworks in developing economies is not the same as in developed economies. The innovation systems in developed countries are dedicated to maintain or improve an already established level of competitiveness and growth, whereas in developing countries they have the task of catching-up combined with problems of weak competitiveness level.

- The petroleum technology in Libyan oil sector is not developed successfully, that attributed particularly, as investigated in this study, to some remarkable causes, namely:

  - Poor drivers to petroleum technology development in terms of: 1) funding of R&D activities, 2) significance of technology development for national economy at petroleum organizations and government level, 3) role of Libyan Government towards petroleum technology development, and 4) scientific and technological interactions between the key players in Libyan oil industry.

  - Weak enablers to petroleum technology development such as: 1) involvement in R&D activities; 2) self-dependence in doing R&D activities; 3) rate of formulating the technology development process; 4) competency of native technical teams to assimilate the technologies being utilized along various petroleum operations; 5) self-dependence in conducting training and development schemes; 6) absorptive capacity of research community to acquire, absorb and develop technological knowledge; 7) conceptualization capability of research community to build shared vision, formulate technology strategy and explore at the end of the day possible technological opportunities; 8) learning climate towards developing technology; and 9) self-dependence of technical oil services companies in private sector to execute their own work.

  - Poor scientific and technical output of Libyan oil sector in terms of: 1) rate of producing research papers and articles, 2) rate of producing technical bulletins, technical standards, technical directives, scientific books, and technical performance reports, 3) rate of applied and granted technological patents, technical copyrights and trademarks, 4) rate of issuing technological know-how licences, and 5) rate of performing technical consultations and industrial designs.

  - Strong influence of barriers to technology development at Libyan oil sector as a consequence of impact of the following factors: 1) High barriers to successful R&D projects and technology development at technological competence domain. 2) High barriers at private companies of technical oil services to support action plans of technology development. 3) Effect of globalization on sectoral efforts for technological acquisition in terms of high dependence on foreign technology supplier. This in turn reduces the chance for native suppliers to innovate and create sustainable competitive advantages. 4) Temperate barriers to inward FDI in favour of developing technologies. 5) Sensible influence of organization culture spread at the research community against some valuable principles by which the productivity of personnel can be enhanced.

- The main determinants of technological catching-up for developing countries at sector level that have been investigated in this study are basically confined to:

  - *Targeting the strategic technological opportunities* which include formulating the technology strategy both at sector and organization levels.
  - *Generating technological knowledge* through stimulating the research and development, building technological catching-up capacity, enhancing organizational learning, and promoting skills supply & attracting talents.
  - *Turning ideas into business* by means of building innovative organization, boosting technological entrepreneurship, and commercializing innovative efforts.
  - *Driving the innovation business* through enabling the innovation culture, and strengthening the institutional framework & policies.
  - *Monitoring the innovation performance* by way of setting up a system of excellence and auditing & improving technological performance.

- The absorptive capacity is a key organizational resource for technological change. A set of organizational determinants that may influence the absorptive capacity is statistically investigated in this study. The resulted conclusion reveals that the learning climate and conceptualization capacity of teams influence positively team's absorptive capacity. This leads to consider that, the learning climate and conceptualization capacity are significantly essential for increasing the team's absorptive capacity.

8.2 RECOMMENDATIONS

- Execution of the main pillars of management framework of technology development in Libyan oil sector should be confined to the prioritization shown in table 8.1.

PRIORITY NO.	PILLAR ACTIVITY	BENEFIT
1	*GENERATING TECHNOLOGICAL KNOWLEDGE*	– Enhancing sectoral body of knowledge through continuous accumulation of technological knowledge that will be obtained by local knowledge generation, problem solving and learning process and by inward knowledge spillovers.
2	*TARGETING TECHNOLOGICAL OPPORTUNITIES*	– At the macro-level, such activity will enable the Libyan government to find out a strategic approach to harness the innovative potential of its respective petroleum capabilities. Any plans that could be designed for S&T at Libyan oil sector will provide a degree of visibility for that sector to prioritize its current commitments and future orientation to meet petroleum technological challenges. – At the micro-level, the Libyan oil organizations will be able accordingly to exploiting and maintaining their technical capitals to attain value-based technological opportunities.
3	*TURNING IDEAS INTO BUSINESS*	– Enable boosting business entrepreneurship in order to create innovative investments that can be grown under conditions of risk and uncertainty. – Facilitate commercializing the innovative efforts of R&D activities that link economic value creation to economic value realization. – Help building consequently innovative organizations in Libyan oil sector that would be capable to generate concepts, identify market needs, develop and introduce products and processes to the marketplace.
4	*DRIVING INNOVATION BUSINESS*	– Enabling innovation culture in order to embodies norms of creativity & change within the human resources towards supporting the strategic goals of Libyan oil sector.

		– Strengthening institutional framework towards supporting national innovation and competitive position in the global arena.
5	*MOINTERNING INNOVATION PERFORMANCE*	– Help setting up sectoral system of excellence and improving technological performance.

Table (8.1): Prioritization of Pillars of Management Framework for Technology Development

- The Government of Libya should give serious considerations to providing mechanisms that permit to solve the most current problematic factors for doing business in Libya that impede building of catching-up capacity at national level, namely: 1) Inadequate supply of infrastructure. 2) Access to financing support in terms of venture capital. 3) Inefficient government bureaucracy. 4) Political and administrative corruption. 5) Policy instability. 6) Restrictive labour regulations. 7) Inadequately well-educated workforce. 8) Weak of overall environment for business and productive enterprises. 9) Low level of financial market sophistication. 10) Lack of governmental policy framework and coherence of structures for R&D and technological innovation. 11) Weak level of overall sectoral funding for R&D.

- The Libyan Government should play an essential role to support innovation and nations' competitive position in the global arena. This can be done through developing a well-purposeful institutional framework that constitutes a set of vital regulations and policies to ensure: 1) Creating a stable political system towards permitting economic growth. 2) Establishing the good governance, which is a crucial element for catching-up, to protect the property rights and human rights, subdue the regulatory burden, strengthen the justice system, combat corruption, and enforce rule of law & order. 3) Reforming the management system at high levels of industrial sectors. 4) Enhancing competition and preventing monopolies that can result in under-innovation and protecting the society against possible abuse by firms. 5) Facilitating strategic orientation and building innovative capabilities. 6) Developing strong research organizations to foster proactive involvement in the acquisition, development and transfer of technology. 7) Supporting initiatives of adoption, adaptation, and diffusion of technology and related know-how. 8) Developing strong financial institutions capable of supporting sustained technical progress. 9)

Establishing the educational and training systems capable to deliver the kind of skills in demand and the adequacy of national resources base. 10) Spurring creativity and entrepreneurship. 11) Protection of intellectual property rights. 12) Enhancing interactions of university-government-industry. 13) Developing strategic alliances with compatible countries to enhance technological progress and strengthen partnership. 14) Inflow of foreign direct investment for technological development. 15) Ability of organizations to meet established objectives. 16) The performance of organizations that assure quality, relevance and sustainability, and the capacity to respond to changing needs and opportunities. 17) Positive technology knock-on effect to ecosystem and society.

- The use of government's purchasing power can be of a benefit to promote innovation all over the Libyan economy. That can be accomplished by setting quality and performance standards for the commodities and services it purchase in order to force organizations to be more innovative.

8.3 FUTURE WORK

- Implementation of the proposed framework for technology development should rest primarily on a complementary scale-up manufacturing infrastructure, either at national or sectoral level, with proven capacity to design, modelling, prototyping, piloting and producing a particular technology embedded in terms of end product or process. This urge the Libyan Government to pay a considerable attention to develop and support the manufacturing industry in Libya especially machine tools enterprises (capital-goods sector), which are extremely needed for the realization of all innovations, whether incremental or radical. Considering the import of capital-goods as the only path for local industrialization may in effect hold back any natural sequence of industrial development, principally the sequential development of domestic machinery industry. Therefore, the importance of capital-goods sector for technological development in Libya can not be doubted. This can lead to suggestion of a future research work in this field to build an in depth understanding about the key causes, determinants and related factors driving the development of this industry locally.

- Application of the EFQM excellence model for assessment of innovation performance in Libyan oil sector requires a profound adaptation process, which is out of scope of this study. This adaptation is needed to configuring the structure and content of that model (e.g., measures of excellence, sub-criteria, relevant appraisal questions, and system of scoring) in order to meet the nature of managerial and technical activities in Libyan oil organizations. This adaptation is very crucial process that has to be considered in a future research work towards accommodating the Libyan oil sector for the excellence.

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APPENDICES

APPENDIX A

QUESTIONNAIRE ON TECHNOLOGICAL DEVELOPMENT COMPETENCE IN LIBYAN OIL SECTOR

I. NATIONAL PETROLEUM RESEARCH INSTITUTE

II. NATIONAL OIL COMPANIES

Section One: Organization Profile

1.1 Business-related Field (For national petroleum research institute only)
(Please select the proper box(es)).

❑ Upstream Industry ❑ Midstream Industry ❑ Downstream Industry

1.2 Business Type *(Please select the proper box(es)).* (For national oil companies only)

❑ Petroleum Exploration ❑ Petroleum Production ❑ Oil Refining

❑ Petrochemical Manufacturing ❑ Chemical Manufacturing ❑ Gas Processing

1.3 Organization Size *(Please select the proper box)*

❑ Less than 100 employees ❑ 100-299 employees ❑ 300- 499 employees

❑ 500-700 employees ❑ Other *(Please specify)* …………………………...…………

1.4 Organization Age *(Please specify the establishing date of your organization)* …. / …. /……………..

1.5 Organization Ownership *(Please select the proper box)*

❑ Public Ownership ❑ Shared Ownership *(Please specify % of public ownership)* ……….…….

1.6 Source of Fund *(Please select the proper box(es))*

❑ Public Fund ❑ Organization's Income Fund ❑ Private Fund ❑ International Fund

Section Two: Characteristics of Technological Capabilities

2.1 Involvement in Research and Development (R&D)

- Does your organization use to, or intend to, put into practice any kind of the following research types? *(Please select the proper option(s))*

RESEARCH ACTIVITIES	Basic Research[1]		Applied Research[2]		None
	Available	To be Available	Available	To be Available	
Option	O	O	O	O	O

[1] *It is experimental or theoretical work undertaken primarily to generate new scientific knowledge about physical, biological and social phenomena, without any particular application of that knowledge.*

[2] *It is geared towards solving particular technological problems and results often in novel or improved technology.*

- If so, does your organization carry out accordingly, or intend to carry out, any kind of the following experimental development? *(Please select the proper option for each statement)*

EXPERIMENTAL DEVELOPMENT ACTIVITIES[1]	Available	To be Available	None
– Design of novel product *(e.g., new material, new device, new component, etc.)*	o	o	o
– Design of novel process *(e.g., new exploration technique, new drilling method, new well logging technique, new technique for oil & gas production, new process of petrochemical manufacturing, new dehydration technique, new distillation technique, new EOR technique, reformulated fuel process, etc.)*	o	o	o
– Constructing prototype[2] for novel product	o	o	o
– Constructing pilot plant[3] for novel process	o	o	o
– Testing of prototypes/pilot plant for feedback R&D	o	o	o
– Product modification *(e.g., incremental innovation, imitative innovation through reverse engineering, etc.)*	o	o	o
– Process modification *(e.g., incremental innovation, imitative innovation through reverse engineering, etc.)*	o	o	o
– Developing advanced software package *(e.g., new simulation package, new PLC software, design of new database & algorithms, new expert system, new operating system for server or PC, new computer programming package, etc.)*	o	o	o
[1] *They refer to the activities involved in putting inventions, discoveries or knowledge to practical use.*			
[2] *It is an original model constructed to include all the technical characteristics and performance of the new product.*			
[3] *It is a trial facility where the new process is tried out and revised.*			

2.2 R&D Priorities

- What are the R&D priorities for your organization that aims to achieve? *(Please rank orderly the following options, i.e.,1,2,3,…,13)*

R&D PRIORITIES	Rank
– Reduction of production cost	
– Competition purpose	
– Developing international outlook	
– Waste reduction	
– Introducing novel or improved process	
– Problem solving for technical operations	
– Building technological self-reliance	
– Meeting technology demand	
– Enhancing productivity of technical operations	
– Increasing stock of knowledge	

– Introducing novel or improved product	
– Meeting globalization challenges	
– Targeting strategic technological opportunities	

2.3 R&D Dependency

- In case your organization carries out R&D activities, what is the implementation mode being utilized to manage and execute those activities in order of your organization capabilities? *(Please select the proper option(s) for each statement)*

R&D CORNERSTONES	**Implementation Mode**			
	In-House	**National Collaboration**	**Foreign Collaboration**	**None**
– Formulating of R&D strategy[1]	O	O	O	O
– Implementing of R&D strategy	O	O	O	O
– Research design[2]	O	O	O	O
– Experiment design[3]	O	O	O	O
– Planning of research project[4]	O	O	O	O
– Planning of development project	O	O	O	O
– Implementing of research project	O	O	O	O
– Implementing of development project	O	O	O	O
– Monitoring of research project[5]	O	O	O	O
– Monitoring of development project	O	O	O	O
[1] *R&D strategy is a comprehensive master plan stating how the organization will achieve its R&D mission and objectives. In other words, it is the process of setting long-range plans for the effective management of R&D opportunities and threats in light of corporate strengths and weaknesses of the organization.*				
[2] *To conceive and outline the research structure such as problem formulation, concept & uncertainty mapping, research method, analysis technique, observations manipulation, results evaluation and outcomes expectation.*				
[3] *To plan the experiment structure such as experiment method, sampling method, estimating measurement uncertainty, verifying validity, assessing reliability of measurement and specifying measurement level & scaling.*				
[4] *Allocating and scheduling resources to complete activities of research project.*				
[5] *The process of measuring actual research achievement against planned achievement, analyzing variance, evaluating possible alternatives, and taking appropriate corrective action whenever needed.*				

2.4 Generating of R&D Ideas

- On which basis the generation of ideas for R&D projects at your organization is being formulated? *(Please select the proper option for each statement)*

SOURCE OF GENERATING IDEAS	**Regularly**	**Occasionally**	**Rarely**	**None**
– Internally, involving top management and all researchers of interest.	O	O	O	O
– Locally, involving government initiatives.	O	O	O	O

– Locally, involving collaboration of universities, research institutes and consultancies	o	o	o	o
– Externally, involving collaboration of universities, research institutes and consultancies.	o	o	o	o
– Customer request *(e.g., national oil companies, foreign oil companies, government agencies, international market demand, etc.)*	o	o	o	o

2.5 Modelling of Technological Development

- Based on which model(s) does your organization use to formulate the process of technology development? *(Please select the proper option for each statement)*

TECHNOLOGICAL DEVELOPMENT MODEL	Regularly	Occasionally	Rarely	None
– Science-Technology Push[1]	o	o	o	o
– Network Model [2]	o	o	o	o
– Market Pull [3]	o	o	o	o
– Interactive Model [4]	o	o	o	o
[1] *Simple linear sequential process; emphasis on R&D, the market is a recipient of the fruits (output) of R&D.*				
[2] *Emphasis on knowledge accumulation and external linkages.*				
[3] *Simple linear sequential process; emphasis on marketing, the market is the source for directing R&D; R&D has a reactive role.*				
[4] *Combination of push and pull models.*				

2.6 Structure of R&D Facilities *(Please specify the R&D facility available at your organization)*

R&D FACILITIES[1]	Availability	
	Yes	No
– Exploration and geology– related laboratories/workshops	o	o
– Drilling and well completion – related laboratories/workshops	o	o
– Production engineering – related laboratories/workshops	o	o
– Reservoir engineering – related laboratories/workshops	o	o
– Petroleum refinement – related laboratories/workshops	o	o
– Petrochemicals – related laboratories/workshops	o	o
– Metallurgy – related laboratories/workshops	o	o
– R&D space[2] *(If so, please specify the total area in square meters ……………………..)*	o	o
– Internet/Intranet *(If so, please specify internet connection speed ……………Gbps)*	o	o
– In-house scientific database	o	o
– Technical library	o	o
– Issuing of scientific periodicals	o	o

– Joining of international scientific databases	O	O
– Joining of calibration/accreditation system *(Domestically or internationally)*	O	O
– Joining of benchmarking system *(Domestically or internationally)*	O	O
– Joining of peer review system[3] *(Domestically or internationally)*	O	O
– Performance self-assessment system	O	O
– Quality management system	O	O
– Technology intelligence system[4]	O	O
– Creating spin-off entrepries[5] through technological incubators	O	O
[1] *They include all facilities used to practice R&D activities.*		
[2] *It encompasses all area dedicated for R&D activities such as laboratories, offices and meeting rooms.*		
[3] *It consists of the exchange of tools, methods and experience between policy-makers of peer organizations on the basis of information about relative performance.*		
[4] *It is a source of information on international R&D activities being executed towards technology development.*		
[5] *New small companies established to commercialize the knowledge and skills of a university or corporate research team in terms of new technologies. Many universities, research institutes and large companies establish dedicated seed funds to stimulate spin-off activities.*		

2.7 Scientific and Technical Output

- To what extent do you believe your organization's scientific and technical output looks like? *(Please select the proper option for each statement)*

OUTPUT	Regularly	Occasionally	Rarely	None
– Research papers	O	O	O	O
– Scientific articles	O	O	O	O
– Technical bulletins	O	O	O	O
– Technical standards (For national petroleum research institute only)	O	O	O	O
– Technical directives	O	O	O	O
– Technical consultation *(i.e., studies)*	O	O	O	O
– Technical performance reports	O	O	O	O
– Scientific books	O	O	O	O
– ePublications[1]	O	O	O	O
– Technical know-how *(i.e., licences)*	O	O	O	O
– Applied patents *(i.e., under verification)*	O	O	O	O
– Granted patents	O	O	O	O
– Technical copyrights[2]	O	O	O	O

– Industrial designs	O	O	O	O
– Trademarks[3]	O	O	O	O
[1] *Showing some selected domestic and/or international publications on your organization's website.*				
[2] *Copyright deals with the rights of intellectual creators in their creation such as books, technical drawings, technical maps, photographic works, software applications, technical motion-pictures, etc.*				
[3] *Trademark is a distinctive name, mark or symbol that is identified with a specific product(s).*				

2.8 Competency for Technology Assimilation

- Could you please indicate the current capacity extent of your organization's technical staff for absorption of utilized technology? *(Please select the proper option(s) for each statement).*

(For national petroleum research institute only)

TECHNOLOGICAL DOMAIN	**Utilization Mode**			
	In-House	**National Collaboration**	**Foreign Collaboration**	**None**
– Seismic Processing & Interpretation	O	O	O	O
– Geological Mapping	O	O	O	O
– Sedimentology Analysis	O	O	O	O
– Lithological Interpretation	O	O	O	O
– Petrographic Analysis	O	O	O	O
– Remote Sensing	O	O	O	O
– Biostratigraphic Analysis	O	O	O	O
– Well Core Analysis	O	O	O	O
– Geochemistry Analysis	O	O	O	O
– Formation Evaluation	O	O	O	O
– Well Log Analysis	O	O	O	O
– Reservoir Fluids Analysis	O	O	O	O
– Drilling Fluids Analysis	O	O	O	O
– Crude Oil Evaluation	O	O	O	O
– Reservoir Characterization	O	O	O	O
– Reservoir Simulation	O	O	O	O
– Formation Damage Analysis	O	O	O	O
– Enhanced Oil Recovery	O	O	O	O
– Petroleum Products Analysis	O	O	O	O
– Petrochemicals Analysis	O	O	O	O
– Characterization & Remediation of Contaminated Aquifers	O	O	O	O
– Material & Corrosion Treatment	O	O	O	O

– Miscellaneous Chemical Analysis	o	o	o	o
– Miscellaneous Biological Analysis	o	o	o	o

(For national oil companies only)

TECHNOLOGICAL DOMAIN	Utilization Mode			
	In-House	National Collaboration	Foreign Collaboration	None
– Seismic Operations	o	o	o	o
– Exploratory Drilling	o	o	o	o
– Geological Mapping	o	o	o	o
– Remote Sensing	o	o	o	o
– Formation Evaluation	o	o	o	o
– Geographic Information System	o	o	o	o
– Drilling Operations	o	o	o	o
– Well Bore Stability	o	o	o	o
– Well Control and Drilling Optimization	o	o	o	o
– Well Logging	o	o	o	o
– Well Completion Operations	o	o	o	o
– Well Servicing & Work over	o	o	o	o
– Reservoir Characterization	o	o	o	o
– Reservoir Simulation	o	o	o	o
– EOR Processes	o	o	o	o
– Gas Condensate Reservoir Analysis	o	o	o	o
– Production Performance Prediction and Improvement	o	o	o	o
– Formation Damage Analysis	o	o	o	o
– Oil and Gas Well Stimulation	o	o	o	o
– Surface Production and Artificial Lift	o	o	o	o
– Characterization & Remediation of Contaminated Aquifers	o	o	o	o
– Operation & Control of Refining Processes	o	o	o	o
– Maintenance of Refineries	o	o	o	o
– Operation & Control of Petrochemicals Production	o	o	o	o
– Maintenance of Petrochemicals Plants	o	o	o	o
– Operation & Control of Gas Processing	o	o	o	o
– Maintenance of Gas Processing Facilities	o	o	o	o
– Manufacturing of Machinery Spare Parts	o	o	o	o

2.9 Inward Technology Transfer

- What are the manners through which petroleum technology being transferred into your organization? *(Please select the proper option for each statement)*

TECHNOLOGY TRANSFER MANNER	Regularly	Occasionally	Rarely	None
– Equipment/Machinery Acquisition	O	O	O	O
– Process Know-how Licensing	O	O	O	O
– Software Licensing	O	O	O	O
– Technical Support	O	O	O	O
– Technical Joint Ventures	O	O	O	O
– Turnkey Projects	O	O	O	O
– Technical Consultation	O	O	O	O
– Technical Training	O	O	O	O

2.10 Dependency on Foreign Suppliers

- To what extent your organization depends currently on the foreign suppliers to meet its various work necessities? *(Please select the proper option for each statement)*

WORK NECESSITY	Dependency Degree				
	Low	Medium	High	Very High	None
– Machinery	O	O	O	O	O
– Raw Material	O	O	O	O	O
– Spare Parts	O	O	O	O	O
– Technical Support	O	O	O	O	O
– Technical Management	O	O	O	O	O
– Technical Consultation	O	O	O	O	O
– Training and Development	O	O	O	O	O

2.11 Characteristics of Training and Development

- How are the training and development programs being executed at your organization? *(Please select the proper option(s) for each statement)*

TRAINING & DEVELOPMENT PROGRAMS	Execution Mode			
	In-House	National Collaboration	Foreign Collaboration	None
– Seismic Processing & Interpretation (For national petroleum research institute only)	O	O	O	O
– Exploration and Rock Mechanics (For national oil companies only)	O	O	O	O
– Surface Geophysics & Rock Mechanics (For national petroleum research institute only)	O	O	O	O
– Drilling & Well Completion	O	O	O	O
– Petroleum Production Engineering	O	O	O	O

– Reservoir Engineering	o	o	o	o
– Enhanced Oil Recovery	o	o	o	o
– Gas Engineering	o	o	o	o
– Technology of Upstream Laboratory	o	o	o	o
– Petroleum Refining Processes & Catalyst Technology	o	o	o	o
– Petrochemical Technology	o	o	o	o
– Technology of Downstream Laboratory	o	o	o	o
– Oil Field Chemicals	o	o	o	o
– Metallurgy & Corrosion	o	o	o	o
– Waste Management & Minimization	o	o	o	o
– Risk Management of Energy Investments	o	o	o	o
– Environmental Impact Assessment	o	o	o	o
– Petroleum Economics	o	o	o	o
– Scientific Research Design	o	o	o	o
– Experimental Development Techniques	o	o	o	o
– Technology & Innovation Management	o	o	o	o
– Engineering Management	o	o	o	o
– Quality Engineering	o	o	o	o
– Safety & Occupational Health	o	o	o	o
– Maintenance Engineering (For national petroleum research institute only)	o	o	o	o
– Maintenance and Overhauls (For national oil companies only)	o	o	o	o
– Information Technology	o	o	o	o

Section Three: Issues Critical to Developing Technology

3.1 Significance of Petroleum Technology Development in Libya *(Please select the proper box)*

- How important is the incorporation of your organization in developing new technologies to the survival and success of your organization business?

  ❑ Low ❑ Medium ❑ High ❑ Very High

- Does your organization formulate its own strategy to develop technology?

  ❑ Yes *(If so, please provide us with more details)* ❑ No

- Has your organization ever involved by any means in any effort of petroleum technology development?

  ❑ Yes *(If so, please provide us with more details)* ❑ No

- Has your organization ever felt any government commitment or support to set a national or sectoral scientific and technology strategy/policy to developing technology?

  ❑ Yes *(If so, please provide us with more details)* ❑ No

- Has your organization ever received any kind of fund towards technology development from any local/international finance institutions or international oil industry in terms of foreign direct investment?

  ❑ Yes *(If so, please provide us with more details)* ❑ No

3.2 Barriers to Successful R&D Projects

- What do you think the degree of availability of the following barriers that could halt making successful R&D projects at your organization? *(Please select the proper option for each statement)*

R&D BARRIERS	**Degree of Availability**				
	Low	**Medium**	**High**	**Very High**	**None**
– Lack of in-house skills.	O	O	O	O	O
– Lack of individual interest in R&D.	O	O	O	O	O
– Lack of top management interest and commitment to R&D.	O	O	O	O	O
– Poor Interaction with oil companies locally and abroad towards R&D.	O	O	O	O	O
– Weak Interaction with universities and other research institutes.	O	O	O	O	O
– Incapability of your organization to exploit adequately and direct properly its various resources.	O	O	O	O	O
– Management problem within your organization.	O	O	O	O	O
– Unclear R&D strategy at your organization.	O	O	O	O	O
– Lack of proper business environment in general.	O	O	O	O	O
– Inadequate fund for in-house R&D.	O	O	O	O	O
– Dearth of competitive pressure.	O	O	O	O	O
– Public ownership of your organization.	O	O	O	O	O
– Lack of government institutional support to R&D.	O	O	O	O	O
– Lack of foreign partnership in R&D.	O	O	O	O	O
– Research low level *(i.e., Significance & Quality).*	O	O	O	O	O
– Weakness of R&D infrastructure.	O	O	O	O	O
– Research output of your organization is not market –oriented research	O	O	O	O	O

3.3 Barriers to Technology Development

- Below are a number of statements regarding attitudes about hurdles to developing Libyan petroleum technology, please tick one option for each statement?

STATEMENT	Disagree Strongly	Disagree	Neither agree nor disagree	Agree	Agree Strongly
– Being a technology developer organization is worth firstly a strong commitment of top management.	o	o	o	o	o
– Lack of effective national innovation system in Libya is the first obstacle towards technology development.	o	o	o	o	o
– Funding research projects and enhancing reward system in universities and research institutes are more important of any thing else for developing technology.	o	o	o	o	o
– Lack of innovation culture among people at work reduces the likelihood of technology development.	o	o	o	o	o
– Paying attention extremely to solve problems of petroleum operations towards production fluency affects negatively any efforts of technology development in Libyan oil sector.	o	o	o	o	o
– Dearth of national skilled researchers, poor of technical infrastructure and shortage of fund for research projects in Libyan universities and research institutes of both public and private sectors are some of the key barriers for technology development in Libya.	o	o	o	o	o
– Lack of technology development strategy at both government and business levels in Libya contributed directly to lack of any real technology development.	o	o	o	o	o
– Lack of native managerial skills to detect, prioritize and planning for technological change.	o	o	o	o	o
– Weakness of various interactions between government, university/research institutes, and oil companies in Libya worsens the situation of technology development.	o	o	o	o	o
– Lack of native skills for technology development among other stumbling blocks in Libyan oil sector discourages inflow of Foreign Direct Investment (FDI) for technology development.	o	o	o	o	o
– Sense of entrepreneurship[1] and technology incubators[2] are missing elements in Libya towards successful technological innovation.	o	o	o	o	o

[1] *It refers to activities that create new resource combinations to make innovation possible and bringing together the technical and commercial worlds in a profitable way.*

[2] *A business entity (sometimes called a business innovation centre) created to nurture business ideas or new technologies, with the goal of helping those ideas become attractive to venture capitalists. An incubator typically provides physical space and a variety of other services – such as administrative, legal, business, technical – that incubating companies can draw upon to develop their business ideas.*

3.4 Role of Government towards Technology Development

- What kind of intervention does the government take to support the process of technological innovation in Libyan petroleum sector? *(Please select the proper option for each statement)*

GOVERNMENT INTERVENTION	Regularly	Occasionally	Rarely	None
– Maintaining the legal infrastructure to support intellectual property rights.	o	o	o	o
– Supporting national firms to join R&D projects and technology roadmaps through subsidising and providing tax advantage.	o	o	o	o
– Encouraging creativity by accepting successful new ideas and rewarding people involved in those initiatives.	o	o	o	o
– Forming a stable economic environment through steady growth, low inflation, and low interest rates to extend funds by banking system to productive firms.	o	o	o	o
– Attraction of creative people to oil industry by enacting a proper relevant institutional set up.	o	o	o	o
– Increasing motivation and reducing frustration among people at work.	o	o	o	o
– Helping national researchers gain access to overseas research facilities by supporting membership and partnership grants.	o	o	o	o
– Supporting native researchers to collaborate with international partners through fellowships, postgraduate and postdoctoral programs.	o	o	o	o
– Boosting universities, research institutes and oil industry involvement and investment in collaborative research and technology incubators in Libya.	o	o	o	o
– Highlighting the importance of science and technology to Libyan economy, environment and society through releasing national innovation awareness strategy.	o	o	o	o
– Accelerating the commercial application of ideas and research output within oil industry.	o	o	o	o
– Increasing fund to R&D projects in national oil industry.	o	o	o	o
– Improving R&D infrastructure in national universities and research institutes to world-class level. (For national petroleum research institute only)	o	o	o	o
– Enhancing interaction of government –university or research institutes – industry to developing technology.	o	o	o	o
– Strengthening links between native innovators through national/international innovators networks.	o	o	o	o

3.5 Institute Interaction with Oil Companies

- What kind of collaboration does your institute have with the national and foreign oil companies? *(Please select the proper option for each statement)*

INTERACTION TYPE	Regularly	Occasionally	Rarely	None
– Joint research projects with national oil companies.	o	o	o	o

– Joint research projects with foreign oil companies.	o	o	o	o
– Joint publications with national oil companies.	o	o	o	o
– Joint publications with foreign oil companies.	o	o	o	o
– Joint program with national oil companies, universities/research institutes and government to formulate sectoral technology strategy.	o	o	o	o
– Joint program with national oil companies to establishing technology incubator/park.	o	o	o	o
– Joint program with foreign oil companies to establishing technology incubator/park.	o	o	o	o
– Institute conducts technical consultation to national oil companies or vice versa.	o	o	o	o
– Institute conducts technical consultation to foreign oil companies or vice versa.	o	o	o	o
– Joint scientific conferences, seminars or workshops with national oil companies.	o	o	o	o
– Joint scientific conferences, seminars or workshops with foreign oil companies.	o	o	o	o
– Institute conducts training programs for national oil companies' staff or vice versa.	o	o	o	o
– Institute conducts training programs for foreign oil companies' staff or vice versa.	o	o	o	o
– National oil companies use Institute's laboratories or vice versa.	o	o	o	o
– Foreign oil companies use Institute's laboratories or vice versa.	o	o	o	o
– National oil companies sign research contract with institute staff or vice versa *(i.e., part time).*	o	o	o	o
– Foreign oil companies sign research contract with institute staff or vice versa *(i.e., part time)*.	o	o	o	o
– Secondment of institute staff to national oil companies or vice versa.	o	o	o	o
– Secondment of institute staff to foreign oil companies or vice versa.	o	o	o	o
– National oil companies sponsor research projects at institute or vice versa.	o	o	o	o
– Foreign oil companies sponsor research projects at institute or vice versa.	o	o	o	o
– National oil companies share technical information with institute or vice versa.	o	o	o	o
– Foreign oil companies share technical information with institute or vice versa.	o	o	o	o
– Institute introduces technical services to national oil companies or vice versa.	o	o	o	o
– Institute introduces technical services to foreign oil companies or vice versa.	o	o	o	o

– Institute staff conducts lectures and presentations for national oil companies or vice versa.	o	o	o	o
– Institute staff conducts lectures and presentations for foreign oil companies or vice versa.	o	o	o	o
– National oil companies gift equipment to institute.	o	o	o	o
– Foreign oil companies gift equipment to institute.	o	o	o	o

Company Interaction with Petroleum Research Institutes

- What kind of collaboration does your company have with the national and foreign petroleum research institutes? *(Please select the proper option for each statement)*

INTERACTION TYPE	Regularly	Occasionally	Rarely	None
– Joint research projects with national petroleum research institute *(i.e., Libyan Petroleum Institute)*.	o	o	o	o
– Joint research projects with foreign petroleum research institute.	o	o	o	o
– Joint publications with national petroleum research institute.	o	o	o	o
– Joint publications with foreign petroleum research institute.	o	o	o	o
– Joint program with national oil companies, universities/research institutes and government to formulate sectoral technology strategy.	o	o	o	o
– Joint program with national petroleum research institute to establishing technology incubator/park.	o	o	o	o
– Your company conducts technical consultation to national petroleum research institute or vice versa.	o	o	o	o
– Your company conducts technical consultation to foreign petroleum research institute or vice versa.	o	o	o	o
– Joint scientific conferences, seminars or workshops with national petroleum research institute.	o	o	o	o
– Joint scientific conferences, seminars or workshops with foreign petroleum research institute.	o	o	o	o
– Your company conducts training programs for staff of national petroleum research institute or vice versa.	o	o	o	o
– Your company conducts training programs for staff of foreign petroleum research institute or vice versa.	o	o	o	o
– Your company uses laboratories of national petroleum research institute or vice versa.	o	o	o	o
– Your company uses laboratories of foreign petroleum research institute or vice versa.	o	o	o	o
– Your company signs research contract with staff of national petroleum research institute or vice versa *(i.e., part time)*.	o	o	o	o
– Your company signs research contract with staff of foreign petroleum research institute or vice versa *(i.e., part time)*.	o	o	o	o
– Secondment of your company staff to national	o	o	o	o

petroleum research institute or vice versa.				
– Secondment of your company staff to foreign petroleum research institute or vice versa.	o	o	o	o
– Your company sponsors research projects at national petroleum research institute or vice versa.	o	o	o	o
– Your company sponsors research projects at foreign petroleum research institute or vice versa.	o	o	o	o
– Your company shares technical information with national petroleum research institute or vice versa.	o	o	o	o
– Your company shares technical information with foreign petroleum research institute or vice versa.	o	o	o	o
– National petroleum research institute introduces technical services to your company or vice versa.	o	o	o	o
– Foreign petroleum research institute introduces technical services to your company or vice versa.	o	o	o	o
– Staff of national petroleum research institute conducts lectures and presentations for your company or vice versa.	o	o	o	o
– Staff of foreign petroleum research institute conducts lectures and presentations for your company or vice versa.	o	o	o	o
– Your company gifts equipment to national petroleum research institute.	o	o	o	o

3.6 Institute Interaction with Universities or other Research Institutes

- What kind of collaboration does your institute have with the national and foreign universities and institutes? *(Please select the proper option for each statement)*

INTERACTION TYPE	Regularly	Occasionally	Rarely	None
– Joint research projects with national universities or research institutes.	o	o	o	o
– Joint research projects with foreign universities or research institutes.	o	o	o	o
– Joint publications with national universities or research institutes.	o	o	o	o
– Joint publications with foreign universities or research institutes.	o	o	o	o
– Joint program with national universities or research institutes to establishing technology incubator or park.	o	o	o	o
– Joint program with foreign universities or research institutes to establishing technology incubator or park.	o	o	o	o
– National universities or research institutes conduct technical consultation to the institute or vice versa.	o	o	o	o
– Foreign universities or research institutes conduct technical consultation to the institute or vice versa.	o	o	o	o
– Joint scientific conferences, seminars or workshops with national universities or research institutes.	o	o	o	o
– Joint scientific conferences, seminars or workshops with foreign universities or research institutes.	o	o	o	o

– National universities or research institutes conduct training programs for institute staff or vice versa.	o	o	o	o
– Foreign universities or research institutes conduct training programs for institute staff or vice versa.	o	o	o	o
– Institute uses national universities/ research institutes' laboratories or vice versa.	o	o	o	o
– Institute uses foreign universities or research institutes' laboratories or vice versa.	o	o	o	o
– Institute signs research contract with staff of national universities or research institutes or vice versa (*i.e., part time*).	o	o	o	o
– Institute signs research contract with foreign universities or research institutes staff or vice versa.	o	o	o	o
– Secondment of institute staff to national universities or research institutes or vice versa.	o	o	o	o
– Secondment of institute staff to foreign universities or research institutes or vice versa.	o	o	o	o
– Institute sponsors research projects at national universities or research institutes or vice versa.	o	o	o	o
– Foreign universities or research institutes sponsor research projects at the institute or vice versa.	o	o	o	o
– Institute shares technical information with national universities or research institutes or vice versa.	o	o	o	o
– Institute shares technical information with foreign universities or research institutes or vice versa.	o	o	o	o
– Institute introduces technical services to national universities or research institutes or vice versa.	o	o	o	o
– Institute staff teaches students at national universities *(i.e., part time)*.	o	o	o	o
– Institute staff teaches students at foreign universities.	o	o	o	o
– Institute staff conducts joint supervision of students at national universities.	o	o	o	o
– Institute staff conducts joint supervision of students at foreign universities.	o	o	o	o
– Institute staff enrols in study programs at national universities.	o	o	o	o
– Institute staff enrols in study programs at foreign universities.	o	o	o	o
– Institute awards grants for postgraduate programs at national universities.	o	o	o	o
– National universities awards scholarships to institute staff.	o	o	o	o
– Foreign universities awards scholarships to institute staff.	o	o	o	o
– Institute gifts equipment to national universities or research institutes or vice versa.	o	o	o	o
– Foreign universities or research institutes gift equipment to institute or vice versa.	o	o	o	o

Company Interaction with Universities or other Research Institutes

- What kind of collaboration does your company have with the national and foreign universities and other research institutes? *(Please select the proper option for each statement)*

INTERACTION TYPE	Regularly	Occasionally	Rarely	None
– Joint research projects with national universities/ other research institutes.	o	o	o	o
– Joint research projects with foreign universities/ other research institutes.	o	o	o	o
– Joint publications with national universities/ other research institutes.	o	o	o	o
– Joint publications with foreign universities/ other research institutes.	o	o	o	o
– Joint program with national universities/ other research institutes to establishing technology incubator/park.	o	o	o	o
– Joint program with foreign universities/ other research institutes to establishing technology incubator/park.	o	o	o	o
– National universities/ other research institutes conduct technical consultation to your company or vice versa.	o	o	o	o
– Foreign universities/ other research institutes conduct technical consultation to your company or vice versa.	o	o	o	o
– Joint scientific conferences, seminars or workshops with national universities/ other research institutes.	o	o	o	o
– Joint scientific conferences, seminars or workshops with foreign universities/ other research institutes.	o	o	o	o
– National universities/other research institutes conduct training programs for your company staff or vice versa.	o	o	o	o
– Foreign universities/ other research institutes conduct training programs for your company staff or vice versa.	o	o	o	o
– Your company uses laboratories of national universities/ other research institutes or vice versa.	o	o	o	o
– Your company uses laboratories of foreign universities/ other research institutes or vice versa.	o	o	o	o
– Your company signs research contract with staff of national universities/other research institutes or vice versa *(i.e., part time)*.	o	o	o	o
– Your company signs research contract with staff of foreign universities/other research institutes staff or vice versa.	o	o	o	o
– Secondment of your company staff to national universities/other research institutes or vice versa.	o	o	o	o
– Secondment of your company staff to foreign universities/other research institutes or vice versa.	o	o	o	o
– Your company sponsors research projects at national universities/other research institutes or vice versa.	o	o	o	o
– Your company sponsors research projects at foreign universities/other research institutes or vice versa.	o	o	o	o
– Your company shares technical information with national universities/other research institutes or vice	o	o	o	o

versa.				
− Your company shares technical information with foreign universities/research institutes or vice versa.	o	o	o	o
− Your company introduces technical services to national universities/other research institutes or vice versa.	o	o	o	o
− Your company introduces technical services to foreign universities/other research institutes or vice versa	o	o	o	o
− Your company staff teaches students at national universities *(i.e., part time)*.	o	o	o	o
− Your company staff teaches students at foreign universities.	o	o	o	o
− Your company staff conducts joint supervision of students at national universities.	o	o	o	o
− Your company staff conducts joint supervision of students at foreign universities.	o	o	o	o
− Your company staff enrols in study programs at national universities.	o	o	o	o
− Your company staff enrols in study programs at foreign universities.	o	o	o	o
− Your company awards grants for postgraduate programs at national universities.	o	o	o	o
− Your company awards grants for postgraduate programs at foreign universities.	o	o	o	o
− National universities awards scholarships to your company staff.	o	o	o	o
− Foreign universities awards scholarships to your company staff.	o	o	o	o
− Your company gifts equipment to national universities/other research institutes.	o	o	o	o
− Your company gifts equipment to foreign universities/other research institutes.	o	o	o	o

III. RESEARCH AND DEVELOPMENT COMMUNITY

Section One: Respondent Profile

1.1 My Profession is … *(Please select the proper box)*

❑ Senior Researcher ❑ Researcher ❑ Senior Assistant Researcher ❑ Assistant Researcher

1.2 My Experience is … *(Please select the proper box)*

❑ > 20 years ❑ 16-20 years ❑ 11-15 years ❑ 5-10 years ❑ < 5 years

1.3 My Scientific Qualification is … *(Please select the proper box)*

❑ PhD ❑ PhM ❑ MSc ❑ BSc ❑ HDip

1.4 My Place of Work is … *(Please select the proper box)*

❑ Research Institute ❑ University ❑ Oil Company

Section Two: Characteristics of Work Environment

2.1 Job Satisfaction *(Please select the proper option for each statement)*

STATEMENT	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
– Each research task assigned to me is quite identified and understandable.	o	o	o	o	o
– My job gains me a variety of skills.	o	o	o	o	o
– I feel my job has a significant impact on my organization outcome.	o	o	o	o	o
– My job gives me a degree of choice and control over the work.	o	o	o	o	o
– I measure regularly my work performance through feedback action of my bosses.	o	o	o	o	o
– My salary and incentives rewarded to me are quite compatible with nature of my job.	o	o	o	o	o
– R&D goals of organization I work for are quite accepted and possible.	o	o	o	o	o
– Our bosses encourage us to contribute towards developing our job through appreciated initiatives and meaningful new ideas.	o	o	o	o	o
– I feel my job is quite secured under working conditions and institutional set-up being applied (i.e., firing action is highly reviewed and assessed).	o	o	o	o	o

2.2 Interpersonal Relationships: *(Please select the proper option for each statement)*

STATEMENT	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
– The way my organization treats its employee's equity effects my work behaviour.	o	o	o	o	o
– In my organization, I usually feel a considerable respect and dignity exchanged between all employees.	o	o	o	o	o
– My job offers me a climate of trust, friendly interaction and openness to others.	o	o	o	o	o
– Within my research group, a sense of teamwork is quite apparent.	o	o	o	o	o
– Most members of my research team are committed to maintaining our group harmony and reducing interpersonal conflicts.	o	o	o	o	o

2.3 Information and Communication Process: *(Please select the proper option for each statement)*

STATEMENT	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
– My job offers me good accessibility to all technical and non technical Information I need (i.e., through surfing internet, local area network, data bases, work documents, library, telephone inquires, face-to-face communication, participation in scientific events, etc).	o	o	o	o	o
– My job enables me to obtain up-to-date technical Information I look for.	o	o	o	o	o
– In general, flow of information through all parts of my organization is suffering weakness.	o	o	o	o	o
– I often feel work-related information is always shared within all members of our research team.	o	o	o	o	o

2.4 Organization Culture: *(Please select the proper option for each statement)*

STATEMENT	Strongly Disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree
– In Libyan public organizations, individuals enhancing organization welfare rather than personal interests.	o	o	o	o	o
– Among most of Libyan organizations; there is a widespread belief that, loyalty before capability when recruiting or assigning work leaders of all levels.	o	o	o	o	o
– In daily work life of Libyans, time is not much important.	o	o	o	o	o
– Resistance to change is not big barrier in most of Libyan organizations.	o	o	o	o	o
– Most of Libyan individuals believe that, work is worthy to pay much attention as there is real rewarding and promotion systems.	o	o	o	o	o
– In most of Libyan organizations, no real challenging works (i.e., innovative efforts) being seriously considered.	o	o	o	o	o

2.5 Learning Climate *(Please select the proper option for each statement)*

STATEMENT	Very Low	Low	Moderate	High	Very High
– To what extent learning-supportive elements (e.g., learning mistakes are tolerated, conducting	o	o	o	o	o

experimentation is encouraged, etc) are available in your organization?					
– To what extent learning-forced elements (e.g., severe competition, massive work duties, research challenges, constructive criticism, high risk, etc) existing in your organization?	o	o	o	o	o
– To what extent does your organization emphasize learning from previous work mistakes and pitfalls?	o	o	o	o	o
– To what extent do training programs being conducted to your research group directly gear to your research work?	o	o	o	o	o
– To what extent is real development of human resources considered in your organization?	o	o	o	o	o

2.6 Managerial System:

- Within your research group, please indicate the degree of leader-member relationship?

  ❑ Very Poor ❑ Poor ❑ Good ❑ Very Good

- Could you please specify to what extent you being subjected to command conflicts between your direct and superior bosses?

  ❑ Regularly ❑ Occasionally ❑ Rarely ❑ None

- To what extent, do you believe, top management of your organization is committed to support research work of your team?

  ❑ Very Low ❑ Low ❑ High ❑ Very High

- To what extent, do you believe, your bosses enable members of your research team to participate actively in decision making process related to your research work?

  ❑ Most of them participate ❑ Few of them participate ❑ None of them participate

- Could you please indicate through which manner you have identified your job description (e.g., purpose of your job, your responsibilities, your duties, job requirements, etc)?

  ❑ Written manner via my boss ❑ Verbal manner via my boss ❑ Self- learning manner

Section Three: Characteristics of Technological Team Capabilities

3.1 Absorptive Capacity *(Please select the proper option for each statement)*

STATEMENT	Very Low	Low	Moderate	High	Very High
– To what extent your organization dedicates to identify and acquire external state-of-the-art technological knowledge (e.g., through know-how licensing, research partnership, technology intelligence system, etc)	o	o	o	o	o
– To what extent your research group is capable to understand and assimilate acquired technological knowledge.	o	o	o	o	o

– To what extent your research group is competent to develop new technological knowledge through acquired knowledge.	o	o	o	o	o
– To what extent your research group is skilful to apply its new developed knowledge to produce new technological outcome (e.g., new product, new process, etc.)	o	o	o	o	o

3.2 Conceptualization Capability *(Please select the proper option for each statement)*

STATEMENT	Very Low	Low	Moderate	High	Very High
– What is the capability degree of your research group to build shared vision about research problem to be solved?	o	o	o	o	o
– To what extent your research team is capable to search and explore possible opportunities for developing technology.	o	o	o	o	o
– To what extent your research team is experienced to participate in formulating R&D Strategy[1] for your organization.	o	o	o	o	o
– To what extent your research team is competent to originate Research Design[2] and Experiment Design[3].	o	o	o	o	o
– To what extent your research team is proficient to determine and evaluate alternatives to solve research problem.	o	o	o	o	o
[1] *R&D strategy is a comprehensive master plan stating how the corporation will achieve its R&D mission and objectives. In other words, it is the process of setting long-range plans for the effective management of R&D opportunities and threats in light of corporate strengths and weaknesses of the organization.*					
[2] *Research design is to conceive and outline the research structure such as problem formulation, concept & uncertainty mapping, research method, analysis technique, observations manipulation, results evaluation and outcomes expectation.*					
[3] *Experiment design is to plan the experiment structure such as experiment method, sampling method, estimating measurement uncertainty, verifying validity, assessing reliability of measurement and specifying measurement level & scaling.*					

Section Four: Issues Critical to Technology Development

4.1 Barriers to Successful R&D Projects

- What do you think the degree of effectiveness of the following barriers against making successful R&D projects in Libyan oil Industry? Please tick the proper option for each statement.

R&D BARRIERS	Degree of Effectiveness				
	Low	Medium	High	Very High	None
– Poor in-house R&D skills.	o	o	o	o	o
– Lack of individual interest in R&D.	o	o	o	o	o
– Lack of top management interest & commitment to R&D.	o	o	o	o	o

– Lack of Interaction between national oil companies towards R&D.	o	o	o	o	o
– Weak Interaction of oil companies with universities and research institutes.	o	o	o	o	o
– Incapability of Libyan oil industry to exploit adequately and direct properly its various resources.	o	o	o	o	o
– Management problem within Libyan oil industry.	o	o	o	o	o
– Unclear R&D strategy.	o	o	o	o	o
– Lack of proper business environment in general.	o	o	o	o	o
– Inadequate fund for in-house R&D.	o	o	o	o	o
– Dearth of competitive pressure.	o	o	o	o	o
– Public ownership of Libyan oil industry.	o	o	o	o	o
– Lack of government institutional support to R&D.	o	o	o	o	o
– Lack of foreign partnership in R&D.	o	o	o	o	o
– Research low level *(i.e., Significance & Quality).*	o	o	o	o	o
– Weakness of R&D infrastructure.	o	o	o	o	o
– Research output of Libyan oil industry is not market –oriented research.	o	o	o	o	o

4.2 Barriers to Technology Development

- Below are a number of statements regarding attitudes about hurdles to developing Libyan petroleum technology, please read each one and click the proper option for each statement?

STATEMENT	Disagree Strongly	Disagree	Neither disagree nor agree	Agree	Agree Strongly
– Developing technology is worth firstly a strong commitment of top management.	o	o	o	o	o
– Lack of effective national innovation system in Libya is the first obstacle towards technology development.	o	o	o	o	o
– Funding appropriately research projects and enhancing reward system in universities and research institutes are more important than any thing else for developing technology.	o	o	o	o	o
– Lack of innovation culture among people at work reduces the likelihood of technology development.	o	o	o	o	o
– Paying attention to solve problems of petroleum operations for production efficiency affects negatively any efforts of technology development in Libyan oil sector.	o	o	o	o	o

– Dearth of national skilled researchers, poor of technical infrastructure and shortage of fund for research projects in Libyan universities and research institutes of both public and private sectors are some of the key barriers for technology development in Libya.	o	o	o	o	o
– Lack of technology development strategy at both government and business levels in Libya contributed directly to lack of any real technology development.	o	o	o	o	o
– Lack of native managerial skills to detect, prioritize and planning for technological change.	o	o	o	o	o
– Weakness of interaction between government, oil companies and university/research institutes in Libya worsens the situation of technology development.	o	o	o	o	o
– Poor native skills for technology development are a stumbling block that discourages inflow of Foreign Direct Investment (FDI) for technology development.	o	o	o	o	o
– Sense of entrepreneurship[1] and availability of technology incubators[2] are missing elements in Libya towards successful technological innovation.	o	o	o	o	o
[1] *Entrepreneurship refers to challenging the risk of making innovation possible and bringing together the technical and commercial worlds in a profitable way.*					
[2] *Technology incubator is a business entity (sometimes called a business innovation centre) created to nurture business ideas or new technologies, with the goal of helping those ideas become attractive to venture capitalists. An incubator typically provides physical space and a variety of other services – such as administrative, legal, business, technical – that incubating companies can draw upon to develop their business ideas.*					

4.3 Priorities for Technological Change

- Below are a number of key elements that could make sense for developing Libyan petroleum technology, please rank them orderly (*i.e.*,*1*,*2*,*3*,…,*9*).

PRIORITIES FOR TECHNOLOGY DEVELOPMENT	**Rank**
– Increasing interactions between national oil companies and research institutes/university.	
– More funding for R&D projects.	
– Increasing government institutional support to R&D.	
– Enhancing foreign partnership/collaboration in local R&D activities.	
– Improving R&D infrastructure (i.e., through improving human capabilities and technological facilities).	
– Enhancing individual interest in R&D through spreading innovation culture.	

– Promoting managerial system of Libyan oil industry.	
– Motivating native research personnel.	
– Formulating effective technology development strategy for Libyan oil sector.	

IV. FOREIGN OIL COMPANIES

Section One: Company Profile

1.1 Business Type: *Please select the proper box(es)*

- ❑ Petroleum Exploration
- ❑ Petroleum Production
- ❑ Oil Refining
- ❑ Petrochemical Manufacturing
- ❑ Gas Processing
- ❑ Technical Oil Servicing

1.2 Company Size: *Please specify the number of employees at:*

- Your company (Libya branch) …………………………………………………...
- Your home company and other branches abroad ……………………………………………….……………..

1.3 Company Age: (*Please specify the date of establishing your company in Libya*) …. /…..... /……..…..

Section Two: Company Involvement in Foreign Direct Investment

2.1 Type of Foreign Direct Investment

- What are types of foreign direct investment your company use to, or intend to, get involved in Libya? *(Please select the proper option for each statement)*

FOREIGN DIRECT INVESTMENT	Available	To be Available	None
– Petroleum Research and Development	O	O	O
– Petroleum Exploration	O	O	O
– Petroleum Production	O	O	O
– Oil Refining	O	O	O
– Petrochemical Manufacturing	O	O	O
– Gas Processing	O	O	O
– Technical Oil Servicing[1]	O	O	O
– Field Chemicals Manufacturing	O	O	O

[1] *Technical oil servicing such as well drilling and workovers, seismic data processing, formation evaluation, reservoir fluids analysis, technical maintenance, safety and occupational health, various construction activities, environmental remedies, various technical consultations, etc.*

2.2 Modes of Entry for Foreign Direct Investment

- What are the manners through which your investment in Libya being, or intended to be, implemented? *(Please select the proper option for each statement)*

MODES OF ENTRY FOR FDI	Available	To be Available	None
– Acquisition of ready-established oil firms	O	O	O

– Acquisition of ready-established oil laboratories	O	O	O
– Petroleum production share agreement	O	O	O
– Technical oil servicing joint ventures	O	O	O
– Establishing new firms of technical oil servicing	O	O	O
– Establishing new laboratories of technical oil servicing	O	O	O
– Establishing new R&D laboratories	O	O	O

2.3 Barriers to Foreign Direct Investment in Technology Development

- What do you think the effectiveness degree of the following barriers against making successful FDI projects towards petroleum technology Development in Libya? *(Please select the proper option for each statement)*

BARRIERS TO FOREIGN DIRECT INVESTMENT	**Degree of Effectiveness**				
	Low	**Medium**	**High**	**Very High**	**None**
– Poor native R&D skills.	O	O	O	O	O
– Lack of native individual interest in R&D.	O	O	O	O	O
– Lack of host government interest & commitment to encourage FDI in R&D.	O	O	O	O	O
– Poor local interaction between oil companies towards R&D.	O	O	O	O	O
– Weak local interaction between oil companies, universities and research institutes.	O	O	O	O	O
– Incapability of your company to attract or exploit adequately native R&D skills.	O	O	O	O	O
– Management problem in general within Libyan oil industry.	O	O	O	O	O
– Unclear FDI strategy at your company for R&D projects.	O	O	O	O	O
– Inappropriate research business environment in Libya.	O	O	O	O	O
– Dearth of competitive pressure environment.	O	O	O	O	O
– Weakness of host government institutional[1] support to in-house R&D.	O	O	O	O	O
– Low level of native Research output *(i.e., Significance & Quality)*.	O	O	O	O	O
– Weakness of Libyan R&D infrastructure.	O	O	O	O	O
– Weakness of Libyan finance institutions infrastructure towards dealing with FDI.	O	O	O	O	O
– High local taxies paid discourage FDI.	O	O	O	O	O

[1] *institutional support encompasses all related legislations, regulations (e.g., intellectual property rights), and policies that aim to sustain R&D projects.*

2.4 Priorities for Encouraging Foreign Direct Investment in Technology Development

- Below are a number of focal enablers that could make sense for encouraging foreign direct investment towards developing petroleum technology in Libya, please rank them orderly (*i.e.,1,2,3,…,11*).

PRIORITIES FOR ENCOURAGING FOREIGN DIRECT INVESTMENT	Rank
– Increasing local interactions between oil companies and research institutes/university.	
– Increasing host government institutional support to in-house R&D.	
– Enhancing foreign partnership/collaboration with local research institutes.	
– Improving indigenous R&D infrastructure (i.e., through improving human capabilities and technological facilities).	
– Enhancing native individual interest in R&D through spreading innovation culture.	
– Promoting managerial system of Libyan oil industry.	
– Motivating foreign direct investment through appropriate local tax policies.	
– Formulating effective sectoral technology development strategy for Libyan oil industry.	
– Strengthening local finance institutions infrastructure.	
– Increasing host government interest & commitment to encourage FDI in R&D.	
– Building good international reputation for Libyan research institutes and universities through world-class research outputs.	

V. PUBLIC UNIVERSITIES AND RESEARCH INSTITUTIES

Section One: Organization Profile

1.1 Business Type *(Please select the proper box)*

❑ University ❑ Research Institute

1.2 Organization Size *(Please specify the number of employees at your organization)*…………………….…..

1.3 Organization Age *(Please specify the date of establishing your organization)* …… / …… / ……………..

1.4 Organization Ownership *(Please select the proper box)*

❑ Public Ownership ❑ Shared Ownership *(Please specify % of public ownership)* ……………..…

Section Two: Characteristics of Technological Activities

2.1 Your Organization Involvement in Research and Development (R&D)

- Does your organization use to, or intend to, put into practice any kind of the following research activities? *(Please select the proper option(s))*

RESEARCH ACTIVITIES	Basic Research[1]		Applied Research[2]		None
	Available	To be Available	Available	To be Available	
Option	O	O	O	O	O

[1] *It is experimental or theoretical work undertaken primarily to generate new scientific knowledge about physical, biological and social phenomena, without any particular application of that knowledge.*

[2] *It is geared towards solving particular technological problems and results often in novel or improved technology.*

- If so, does your organization carry out accordingly, or intend to carry out, any kind of the following experimental development? *(Please select the proper option for each statement)*

EXPERIMENTAL DEVELOPMENT ACTIVITIES[1]	**Available**	**To be Available**	**None**
– Design of novel product related to oil industry *(e.g., new material, new device, new component, etc.)*	o	o	o
– Design of novel process related to oil industry *(e.g., new exploration technique, new drilling method, new well logging technique, new technique for oil & gas production, new process of petrochemical manufacturing, new dehydration technique, new distillation technique, new EOR technique, reformulated fuel process, etc.)*	o	o	o
– Constructing prototype[2] for novel product	o	o	o
– Constructing pilot plant[3] for novel process	o	o	o
– Testing of prototypes/pilot plant for feedback R&D	o	o	o
– Product modification *(e.g., incremental innovation, imitative innovation through reverse engineering, etc.)*	o	o	o
– Process modification *(e.g., incremental innovation, imitative innovation through reverse engineering, etc.)*	o	o	o
– Developing advanced software package *(e.g., new simulation package, new PLC software, design of new database & algorithms, new expert system, new operating system for server or PC, new computer programming package, etc.)*	o	o	o
[1] *They refer to the activities involved in putting inventions, discoveries or knowledge to practical use.*			
[2] *It is an original model constructed to include all the technical characteristics and performance of the new product.*			
[3] *It is a trial facility where the new process is tried out and revised.*			

2.2 R&D Priorities

- What are the R&D priorities for your organization that aims to achieve? *(Please rank orderly the following options, i.e.,1,2,3,…,13)*

R&D PRIORITIES	**Rank**
– Reduction of industrial production cost	
– Competition purpose	
– Developing international outlook	
– Industrial waste reduction	
– Introducing novel or improved process	
– Problem solving for technical operations in Libyan industry	
– Building technological self-reliance	
– Meeting technology demand of industry	

– Enhancing productivity of technical operations in Libyan industry	
– Increasing stock of knowledge	
– Introducing novel or improved product to market	
– Meeting globalization challenges	
– Targeting strategic technological opportunities	

Section Three: Issues Critical to Developing Technology

3.1 Barriers to Successful R&D Projects

- What do you think the degree of effectiveness of the following barriers against making successful R&D projects in your organization? Please tick the proper option for each statement.

R&D BARRIERS	Degree of Effectiveness				
	Low	Medium	High	Very High	None
– Poor in-house R&D skills.	O	O	O	O	O
– Lack of individual interest in R&D.	O	O	O	O	O
– Lack of top management interest & commitment to R&D.	O	O	O	O	O
– Weak Interaction of universities/research institutes with overall Libyan industry.	O	O	O	O	O
– Incapability of your organization to exploit adequately and direct properly its various resources.	O	O	O	O	O
– Management problem within Libyan industry.	O	O	O	O	O
– Unclear R&D strategy at your organization.	O	O	O	O	O
– Lack of proper business environment in general.	O	O	O	O	O
– Inadequate fund for in-house R&D.	O	O	O	O	O
– Dearth of competitive pressure environment.	O	O	O	O	O
– Lack of government institutional support to local R&D.	O	O	O	O	O
– Lack of foreign partnership in local R&D.	O	O	O	O	O
– Research low level *(i.e., Significance & Quality).*	O	O	O	O	O
– Weakness of in-house R&D infrastructure.	O	O	O	O	O
– Research output of Libyan universities and research institutes is not market –oriented research.	O	O	O	O	O

3.2 Priorities for Technological Change

- Below are a number of key elements that could make sense for developing Libyan technology, please rank them orderly (*i.e.,1,2,3,…,9*).

PRIORITIES FOR TECHNOLOGY DEVELOPMENT	Rank
– Increasing interactions between all sectors of Libyan industry and research institutes/university.	
– More funding for R&D projects.	
– Increasing government institutional support to local R&D.	
– Enhancing foreign partnership/collaboration in local R&D activities.	
– Improving local R&D infrastructure (i.e., through improving human capabilities and technological facilities).	
– Enhancing individual interest in R&D through spreading innovation culture.	
– Promoting managerial system of Libyan industry.	
– Motivating native research personnel.	
– Formulating effective national strategy for technology development.	

VI. NATIONAL PRIVATE COMPANIES OF TECHNICAL OIL SERVICES

Section One: Company Profile

1.1 Business Type *(Please select the proper box(es))*

❑ Petroleum Exploration Services ❑ Petroleum Production Services ❑ Oil Refining Services

❑ Petrochemical Services ❑ Gas Processing Services ❑ Maintenance Support

❑ Training & Consultation Services ❑ Construction Services ❑ Material Supply

1.2 Company Size *(Please specify the number of employees at your company)* ……………………………...

1.3 Company Age *(Please specify the date of establishing your company)* …… / …… / ……………………..

1.4 Company Ownership *(Please select the proper box)*

❑ Private Ownership ❑ Shared Ownership *(Please specify % of public ownership)* …………………

Section Two: Characteristics of Technological Activities

2.1 Work Dependency

- What is the implementation mode being used at your company to introduce the following services? *(Please select the proper option(s) for each statement)*

TYPE OF SERVICE	Implementation Mode			
	In-house	National Collaboration	Foreign Collaboration	None
– Technical services[1]	O	O	O	O
– Consultation services	O	O	O	O
– Training services	O	O	O	O

[1] *Technical services introduced by your company to Libyan oil industry (e.g., exploration services, production services, maintenance support, construction services, material supply, refining services, petrochemical services, etc)*

2.2 Your Company Involvement in Research Activities

- Does your company use to, or intend to, put into practice any kind of the following research activities? *(Please select the proper option(s))*

RESEARCH ACTIVITIES	Basic Research[1]		Applied Research[2]		None
	Available	To be Available	Available	To be Available	
Option	O	O	O	O	O

[1] *It is experimental or theoretical work undertaken primarily to generate new scientific knowledge about physical, biological and social phenomena, without any particular application of that knowledge.*

[2] *It is geared towards solving particular technological problems and results often in novel or improved technology.*

2.3 You Company Support to Research Activities

- What kind of interaction does your company offer to support national research community? *(Please select the proper option for each statement)*

INTERACTION TYPE	Regularly	Occasionally	Rarely	None
– Joint research projects with national research institutes or universities.	O	O	O	O
– Joint publications with national petroleum research institutes or universities.	O	O	O	O
– Joint program with national companies, universities/research institutes and government to formulate national/sectoral strategy for technology development.	O	O	O	O
– Joint program with national research institute/universities to establishing technology incubator/park.	O	O	O	O
– Joint scientific conferences, seminars or workshops with national research institutes or universities.	O	O	O	O
– Your company sponsors research projects at national research institute or universities.	O	O	O	O
– Your company awards grants of postgraduate programs to national research institutes.	O	O	O	O
– Your company shares technical information with national research institute or universities.	O	O	O	O

2.4 Barriers to Support Technology Development

- What do you think the effectiveness degree of the following barriers against your company support to making successful petroleum technology Development in Libya?*(Please select the proper option for each statement)*

BARRIERS TO SUPPORT TECHNOLOGY DEVELOPMENT	Degree of Effectiveness				
	Low	Medium	High	Very High	None
– Poor native R&D skills.	O	O	O	O	O
– Lack of native individual interest in R&D.	O	O	O	O	O

– Lack of government interest & commitment to encourage R&D.	o	o	o	o	o
– Poor local interaction between national oil companies towards R&D.	o	o	o	o	o
– Weak local interaction between national oil companies, universities and research institutes.	o	o	o	o	o
– Incapability of your company to support national R&D activities.	o	o	o	o	o
– Management problem in general within Libyan oil industry.	o	o	o	o	o
– Inappropriate research business environment in Libya.	o	o	o	o	o
– Dearth of competitive pressure environment.	o	o	o	o	o
– Weakness of government institutional[1] support to national R&D.	o	o	o	o	o
– Low level of national Research output *(i.e., Significance & Quality).*	o	o	o	o	o
– Weakness of Libyan R&D infrastructure.	o	o	o	o	o
[1] *institutional support encompasses all related legislations, regulations (e.g., intellectual property rights), and policies that aim to sustain R&D projects.*					

2.5 Priorities towards Supporting Research and Development

- Below are a number of key enablers that could encourage national companies of oil services to support research and development towards developing petroleum technology in Libya, please rank them orderly (*i.e.,1,2,3,…,9*).

PRIORITIES TOWARDS SUPPORTING RESEARCH AND DEVELOPMENT	Rank
– Increasing local interactions between oil companies and research institutes/university.	
– Increasing government institutional support to in-house R&D.	
– Improving national R&D infrastructure (i.e., through improving human capabilities and technological facilities).	
– Enhancing native individual interest in R&D through spreading innovation culture.	
– Promoting managerial system of Libyan oil industry.	
– Formulating effective sectoral strategy of technology development for Libyan oil industry.	
– Increasing government interest & commitment to encourage R&D.	
– Building good international reputation for Libyan research institutes/universities through world-class research outputs.	
– Offering opportunities to national companies of oil services to expand their profits.	

APPENDIX B

SELECTING THE SIGNIFICANCE TEST

There are two general types of significance tests: *parametric* and *nonparametric*. Parametric tests are powerful inferential statistics which compare sample statistics with population parameters, and their data are derived from *interval and ratio* measurements. Nonparametric tests, on the other hand, are used to test hypothesis with *nominal and ordinal* data, although parametric tests are sometimes employed in this case. Nonparametric tests may also be used for interval and ratio data, although they may waste much of information available. Parametric tests have greater efficiency when their use is appropriate, but even in such cases nonparametric tests often achieve efficiency as high as 95 percent. This means the nonparametric with sample of 100 will provide the same statistical testing power as parametric test with a sample of 95 (Cooper and Schindler, 2006).

To select the appropriate significance test, the research should consider at least three questions:

– Does the test involve one sample, two samples, or *k* (more than two) samples?

– If two samples or *k* samples are involved, are the individual cases independent or related?

– Is the measurement scale nominal, ordinal, interval, or ratio?

The most frequently used of significance tests by measurement scale and testing situation is listed in table B.1.

MEASUREMENT SCALE	**ONE-SAMPLE CASE**	**TWO-SAMPLE TESTS**		***k*-SAMPLE TESTS**	
		Related Samples	**Independent Samples**	**Related Samples**	**Independent Samples**
NOMINAL	• Binomial • Chi-square one-sample test	• McNemar test	• Fisher exact test • Chi-square two-samples test	• Cochran Q	• Chi-square for *k* samples
ORDINAL	• Kolmogorov-Smirnov one-sample test • Runs test	• Sign test • Wilcoxon matched-pairs test	• Median test • Mann-Whitney U • Kolmogorov-Smirnov • Wald-Wolfowitz	• Friedman two-way ANOVA	• Median extension • Kruskal-Wallis one-way ANOVA
INTERVAL & RATIO	• t-test • Z test	• t-test for paired samples	• t-test • Z test	• Repeated-measures ANOVA	• One-way ANOVA • n-way ANOVA

Source: Cooper& Schindler (2006)

Table (B.1): Statistical Techniques of Significance Tests