Kasdi Merbah University – Ouargla

Faculty of Economic, Commercial, and Management Sciences

Department of Management Sciences

Dissertation submitted in Partial Fulfillment of the Requirements for the Degree of Master in Sciences of Management, Speciality: Management

Titled:

The Role of Research and Development in Achieving Technological Innovation

Case of Study in Shlumberger Company(SLB) during the period (2010-2022)

Prepared by Students:

Ghali Noureddine Ghouali **Bedria Kherfi**

Discussed and Approved in: June 08th 2024

Members of Jury:

Prof / Benchouiha Bachir (University of Ouargla)… ……..……**President**

Prof/ Abderraouf Hadjadj (University of Ouargla……....**Supervisor**

Prof /Nedjmi Saidat (University of Ouargla) ……..…….. **Examiner**

Academic Year:2023-2024

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Dedication

To my parents,

whose love and belief in me have been my foundation. Your sacrifices and guidance have shaped who I am today.

To my brother, Amine, and sisters,

for always cheering me on and reminding me

of the importance of resilience and unwavering support.

I also want to express my gratitude to my uncle, Dr. BENADDA Abdelwahed,

who encouraged me to return to university and strive to excel in my studies,

and to ALI Saliha from the UK, who always believed in my ability

to achieve my goals as long as I set my mind to them.

I extend my thanks to KARKI Heythem, my most trusted and treasured friend.

Thanks to you all for being my pillars of strength.

This accomplishment is dedicated to you…

Ghali Noureddine Ghouali

Dedication

I dedicate this dissertation

To my mother MESSOUADA and my father SAid fortheir inestimable love, their sacrifices, their confidence,their support

and all the values they were able to instillin me.

To my grandmother, for all the affection she hasgiven me

and for her invaluable encouragement.

To my sisters(Farah,Hasina,Karima,Iline,Djahida)and brothers(Hocine,Salim,Mohamed Moncef), fortheir tenderness, their complicity and theirpresence despite the distance that separates us.

To my aunts and uncles of the KHERFI familyand KADI Family, for their words of encouragement and kindness.

Bedria Kherfi

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Lastly, we extend our thanks to everyone who offered help and support, whether near or far. This dissertation would not have been possible without your exceptional support.

Abstract:
This study aims to explores the role of research and development (R&D) in achieving technological innovation at SLB company. The study utilized a descriptive analytical approach to assess R&D activities by calculating input and output indices. The input index considered the company's expenditure on R&D activities and the ratio of R&D workers to total workers, while the output index included metrics such as the number of patents acquired and the development of products, processes, and services. Through a descriptive analytical methodology, the study employed these indicators to evaluate the variables. The results revealed a significant positive correlation between R&D investment and technological innovation at SLB. Specifically, an increase in R&D spending and investment directly correlated with enhanced levels of technological innovation. In summary, the study affirms that R&D investment plays a crucial role in driving technological innovation at SLB.
Key words: R&D, Technological innovation ,Product innovation, Process innovation.

ملخص الدراسة:

تهدف هذه الدراسة إلى استكشاف دور البحث والتطوير في تحقيق الابتكار التكنولوجي في شركة SLB. استخدمت الدراسة المنهج الوصفي التحليلي لتقييم أنشطة البحث والتطوير من خلال حساب مؤشرات المدخلات والمخرجات. يأخذ مؤشر المدخلات بعين الاعتبار إنفاق الشركة على أنشطة البحث والتطوير ونسبة العاملين في مجال البحث والتطوير إلى إجمالي العاملين، في حين يتضمن مؤشر المخرجات مقاييس مثل عدد براءات الاختراع المكتسبة وتطوير المنتجات والعمليات والخدمات. ومن خلال المنهج الوصفي التحليلي، استخدمت الدراسة هذه المؤشرات لتقييم المتغيرات. وكشفت النتائج عن وجود علاقة إيجابية كبيرة بين الاستثمار في البحث والتطوير والابتكار التكنولوجي في SLB. وعلى وجه التحديد، ارتبطت الزيادة في الإنفاق على البحث والتطوير والاستثمار بشكل مباشر بمستويات أعلى من الإبداع التكنولوجي.وفي الختام، تؤكد الدراسة أن الاستثمار في البحث والتطوير يلعب دورًا حاسمًا في دفع الابتكار التكنولوجي في SLB.

الكلمات المفتاحية: البحث والتطوير، الإبتكار التكنولوجي، إبتكار المنتج ، إبتكار العملية

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List of Abbreviations	
R&D	Research & Development
AI	Artificial Intelligence
ROI	Return on Investment
FMCG	the Fast Moving Consumer Goods
SLB	Schlumberger
OECD	Organisation for Economic Co-operation and Development
NSF	National Science Foundation
SMES	Small and Medium-sized Enterprises
CEO	Chief Executive Officer
NACE	Nomenclature of Economic Activities in the European Community
CDM	Conceptual Development Model
PVAR	Panel Vector Autoregression
NYSE	New York Stock Exchange
HES	Halliburton Energy Services
SRPC	Houston for Oilfield Services and in Paris for Development and Research

Introduction

Background:

In the swiftly changing landscape of the 21st century, which is witnessing significant changes, especially in the field of science and technology, and with the expansion of market scope and the alteration of their boundaries, there is an increasing need for institutions to excel in their products and to occupy a competitive position in the local and global market. Therefore, the institution must adapt to these transformations and keep pace with them, finding appropriate solutions by producing new products and processes or making improvements to their current products and processes, which entails activating innovation. To achieve this, it must pay attention to research and development activities, whether in terms of allocating a sufficient budget or providing qualified individuals in numbers sufficient to carry out this activity.

Problem Statement:

Through the above, the following problem statement can be posed:

To what extent have research and development efforts contributed to technological innovation within SLB company, specifically between the years 2010 and 2022?

Research questions:

In order to get the answer of this question, the following sub-questions can be extended:

- What is the level of R&D activity at SLB company ?

- What is the level of technological innovation at SLB company ?

- Is there a relationship between independnt variable R&D and dependent variable technological innovation ?

Resarch hypotheses:

To achieve the aim of the study, the following hypotheses are formulated:

- There is a high level of R&D activity at SLB company.

- There is a high level of technological innovation at SLB company.

- There is a relationship between independnt variable R&D and dependent variable technological innovation.

Research importance:

The importance of the current study from the importance of the Research and development (R&D)that drive play a crucial role in the sustainability of organizations across various industries. R&D initiatives enable companies to innovate, improve their products and services, and adapt to changing market

demands. This continuous improvement is crucial for maintaining a competitive advantage and fostering long-term growth. Technological innovation, driven by R&D, is particularly important as it allows organizations to streamline operations, reduce costs, and introduce cutting-edge solutions that meet emerging customer needs. By investing in R&D, companies can stay ahead of the curve, ensuring their relevance and resilience in an ever-evolving business landscape.

- **Research objectives:**

The objectives of this study include examining the current state of research and development (R&D) at SLB and exploring the role of technological innovation within the company. By analyzing SLB's R&D efforts, the study aims to highlight how the company leverages R&D to drive advancements in the oilfield services sector. Additionally, the study will investigate the impact of technological creativity on SLB's operational efficiency, competitiveness, and ability to meet the evolving needs of the energy industry. Ultimately, this research seeks to provide insights into the effectiveness of SLB's strategies in fostering innovation and sustaining its leadership in the market.

- **Research Choice Reasons:**

There are many reasons that led to choose this topic which are :

Subjectives reasons:

-Personal desire to learn about this topic.

Objectives reasons:

-The research and development is one of the modern topics nowdays at Kasdi Merbah University.

-Submitting the addition on the topic to the university library.

- **Research limitations:**

Spatial limitations: SLB company (SLB)

Temporal limitations: The current study took place from 2010 to 2022

Objective limitations: in this study, Research and Development have been taken as the independent variable and had the following two indicators: (Number of R&D employees and R&D expanditure). And Technological Innovation as the dependent variable, which had the following two indicators: Number of patents, product and process innovation.

- **Research Methodology:**

In order to achieve the objective of research, answering its questions, and try to prove the hypotheses proposed above, a **descriptive approach** was used, which

is compatible with the nature of the study, to explore the influence of research and development on technological innovation in this company.

The field study was conducted at the SLB company which is based in the United States. We collected data from annual reports and a few statistical websites, and we processed it using **Analytical approach.**

Research Reference:

- Scientific articles and reviews
- PhD dissertations
- Books
- Web-sites

Study difficulties:

During this study, We had to face several obstacles, which are:

-It was hard to find suitable organisation for our study which use research and development in it's activities .

- Difficulties in verifying the data due to the constant changes in the annual reports and using several resoureces.

- Lack of references which talk about research and development, especially books.

- There wasn't enough time to conduct the field study, especially with the difficulty of the company's acceptance procedures.

Research structure:

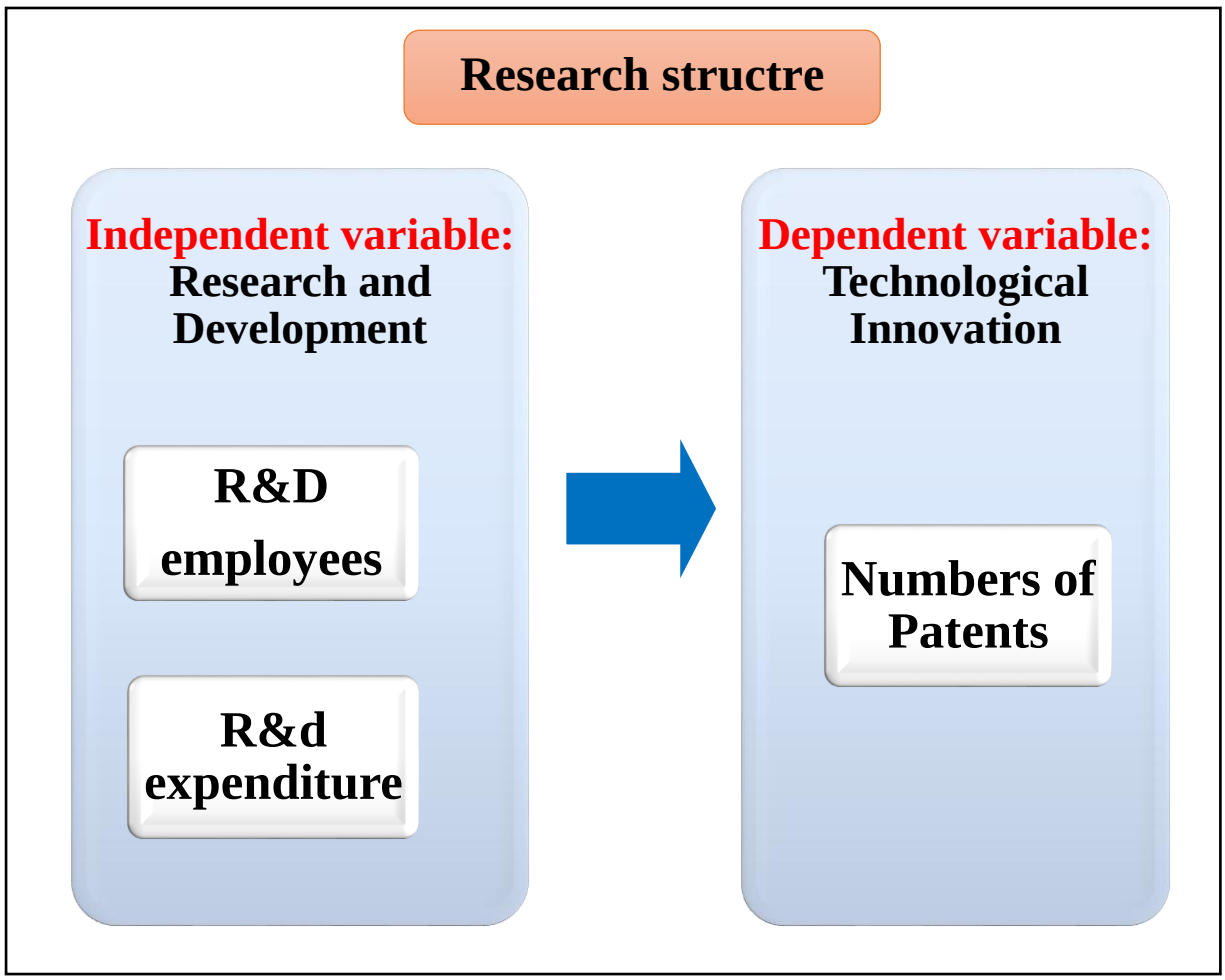
This study is divided into two chapters. Each of the chapters has its specific target and contribution to this study.

Chapter One is divided into two sections, the first one is about outlining conceptual framework for both variables for more clarification for the topic, such as; definitions, types, , dimensions, importance…, related to both research and development (R&D) and technological innovation, the second section is about presenting and discussing previous studies associated with the same subject, followed by a short comparation between the current research in one hand and previous research in other hand.

Chapter two then is dealing with the field study of the role of R&D in achieving technological innovation , divided into two sections, the first one illustrates the research method and tools, the population study described in some details. Whereas, section two demonstrates the results of the study conducted with a discussion. And finally, provides the main findings in conclusions, and suggests recommendations for further researches.

Research Structure:

Figure (1.1): Research structure



Source: made by the students

Chapter one

Literature review and Empirical studies of the Role of Research and Development in achieving Technological Innovation

Preface:

Generating innovative ideas is key to success for all businesses and whole industries. We notice a huge focus on research and development (R&D) nowadays because it has a great potential to create significant breakthroughs and give companies a competitive postion by activating technological innovation.

Through this chapter, We will try to identify many sides of theoretical literature on research and development activity and technological innovation, as well presenting previous studies.Deviding the chapter into two sections as follows:

- **Section one:** Literature review of the role of research and development in achieving technological innovation
- **Section one:** Empirical studies of the role of research and development in achieving technological innovation

1.1. Literature review of The Role of Research and Development in achieving Technological Innovation

1.1.1. Research and Development:

To understand the various aspects related to research and development (R&D) activities, it is necessary to address its concept and types, then specifically its importance, objectives, and characteristics. Additionally, one must consider the key dimensions and indicators, the influencing factors and obstacles, as well as its role within the economic institution.

1.1.1.1. Research and Development ' definition:

In the English dictionary, the word " Research " refers to a detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding."Development" refers to the process in which someone or something grows or changes and becomes more advanced**.(Cambridge dictionary, 2024)**
According to the International Accounting Standards Board of Intangible Assets **(IAS 38,p1493)** :

Research: is original and planned investigation undertaken with the prospect of gaining new scientiftc or technical knowledge and understanding.

Development: is the application of research findings or other knowledge to a plan or design for the production of new or substantially improved materials, devices, products, processes, systems or services before the start of commercial production or use.

Research and Development are distinct functions with different outputs. Research generates knowledge, while Development produces products and processes. **(Brown, & Svenson, 1988: 14)**

The Organization for Economic Cooperation and Development (OECD) defines Research and Development (R&D) that is: "creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture, and society—and to devise new applications of available knowledge " **.(Frascati Manual ,7th ed., OECD 2015:2) .**

Paul Trott, in his book "Innovation Managment And New Product Development" explained that Research and Development R&D as: the purposeful and systematic use of scientific knowledge to improve human welfare and create new products or processes**.(Trott,2017:337)**

According to Fei Chen, Research and Development (R&D) is defined as a strategic investment to create new knowledge, technologies, and products, and its value is particularly important for innovative companies. **(Fei Chen,2022)**

So, Research and Development is a systematic process that involves both generating new knowledge and applying existing knowledge to create tangible products, processes, or services. It's a dynamic cycle of exploration, discovery, and innovation aimed at advancing technology, improving products, and enhancing processes for practical use.

Based on the definitions above,the most crucial aspects of research and development are:

- systematic work.

- strategic investment.

- Based on scientific knowledge.

- purposeful to devise new applications

1.1.1.2. Types of research and development :

The R&D Magazine's Global R&D Funding Forecast reports mention that R&D divided into three types of activity: basic research, applied research and experimental development as defined by the U.S. National Science Foundation (NSF), include: **(R&D Magazine, 2019:6)**

a-Basic research: is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Basic research analyzes properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws. The results of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues. **(Jain et al,2010:7)**

b-Applied research: is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. **(Frascati Manual ,7th ed., OECD 2015:2,3)**

Trott pointed in his book that this activity involves the use of existing scientific principles for the solution of a particular problem. It is sometimes referred to as the application of science. It may lead to new technologies and include the

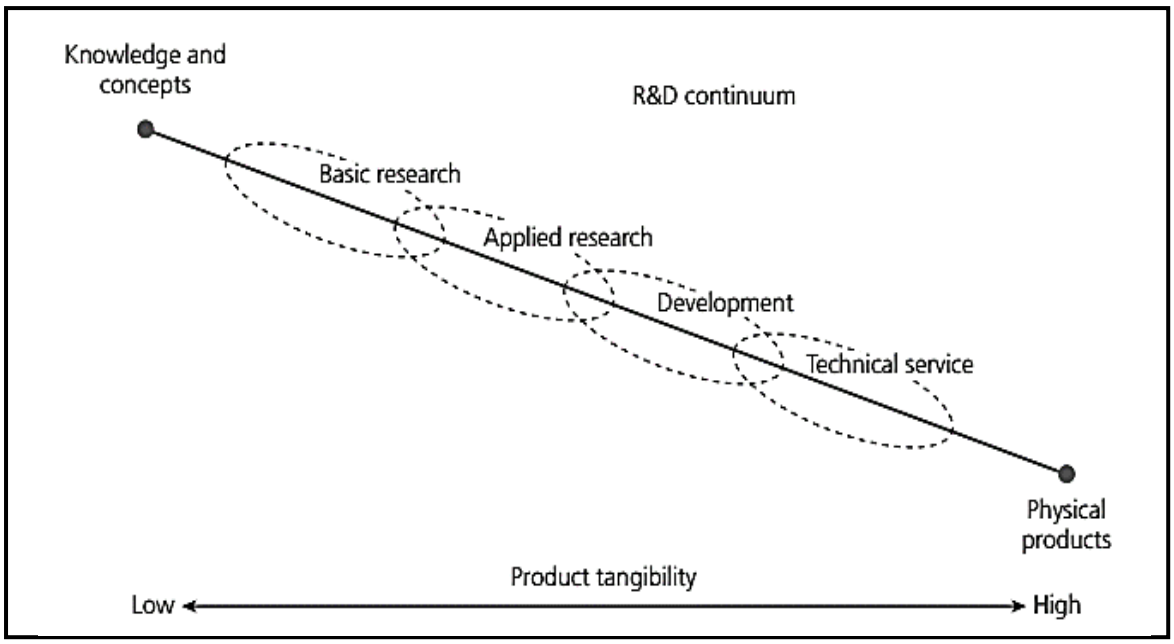
development of patents. It is from this activity that many new products emerge. This form of research typically is conducted by large companies and university departments. **(Trott,2017:316)**

There is a tension between basic and applied research which is is indeed a common challenge. Basic research often follows the curiosity of scientists, while applied research is driven by specific goals or needs of an organisation. Balancing priorities can be tricky, as illustrated by the conflict between pursuing new insights and meeting immediate objectives by supervisors or organisations. **(Jain et al,2010:16)**

c-Experimental development: is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

While Trott add another Type in his book as a more contemporary definition of R&D accoding to Roussel et al. (1991) which includs technical service, and defines the concept as the following figure:

Figure(1-1): The R&D continum

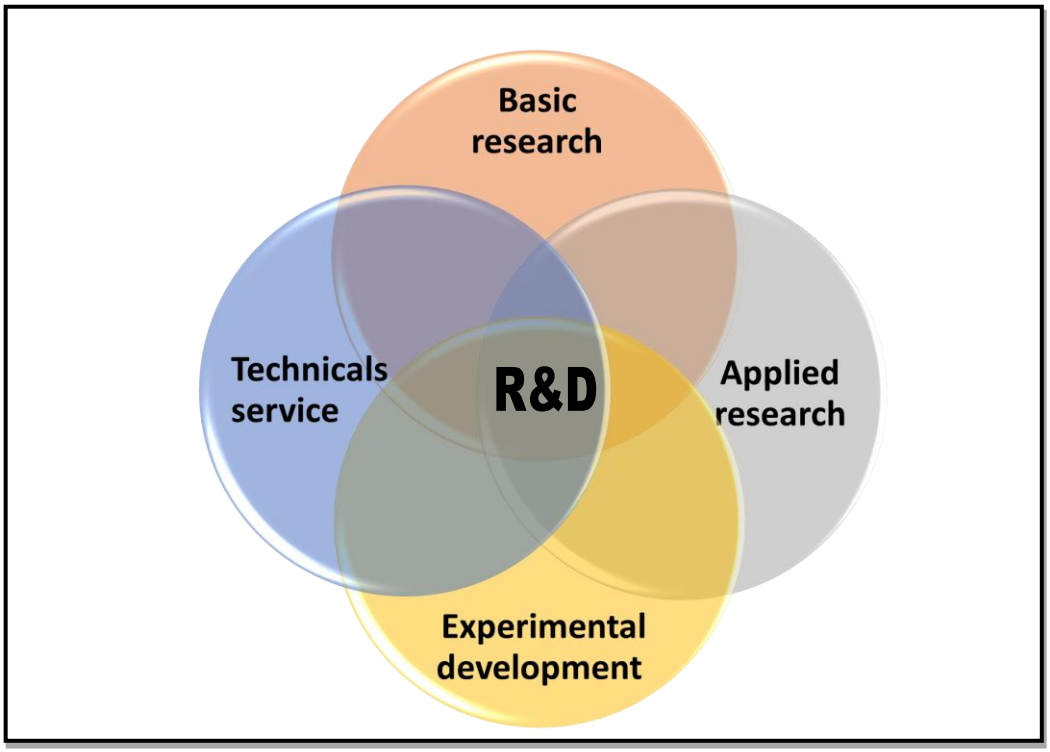


Source: (Trott,2017:306)

d-Technical service focuses on providing a service to existing products and processes. Frequently, this involves cost and performance improvements to existing products, processes or systems. For example, in the bulk chemical industry it means ensuring that production processes are functioning effectively

and efficiently. This category of R&D activity also would include design changes to products to lower the manufacturing costs. For Dyson Appliances, extensive efforts will be employed in this area to reduce the cost of manufacturing its vacuum cleaner, leading to increased profit margins for the company. **(Trott,2017:317)**

Figure(1-2): The R&D types



Source: Made by the Students Based on Previous

1.1.1.3.Research and development risks:

R&D projects are characterized as being high risk and high reward due to their exploratory nature and the potential for significant breakthroughs.(**Luppino, Hosseini, & Rameezdeen, 2014:69)**

(H Erfani , 2019:17,20,22,24,25) mention in his book " **Research and Development: One of the Needs of the World Today is Research and Development** " some potential risks associated with R&D activities:

- **Financial Risks:** R&D projects can be costly, and there is a risk of not achieving the desired outcomes within the allocated budget.
- **Technological Risks:** R&D involves experimentation and innovation, which can lead to technological failures or setbacks.

- **Market Risks:** There is a risk that the products or innovations developed through R&D may not meet market demands or expectations, leading to commercial failure.
- **Competitive Risks:**Failure to keep up with competitors in terms of technological advancements and innovation can pose a risk to the company's market position.
- **Regulatory Risks:** Changes in regulations or compliance requirements can impact R&D projects and outcomes.
- **Intellectual Property Risks:**Lack of proper intellectual property protection can lead to the loss of innovative ideas and potential revenue streams.

And (**Luppino, Hosseini, & Rameezdeen, 2014:70)** added that risks associated with operational aspects are generally related to project management at the execution level. These can include such things as project team morale, communication breakdowns, and lack of clarity and understanding of project objectives and requirements.

Additionally, R&D projects that involve multiple organizations or stakeholders may experience risks related to contractual agreements that may cause cost overruns and missed deadlines.

Therefore, companies should conduct thorough risk assessments and implement mitigation strategies to minimize potential setbacks. **(Gutterman,2023:16).**

1.1.1.4. Research and development stages:

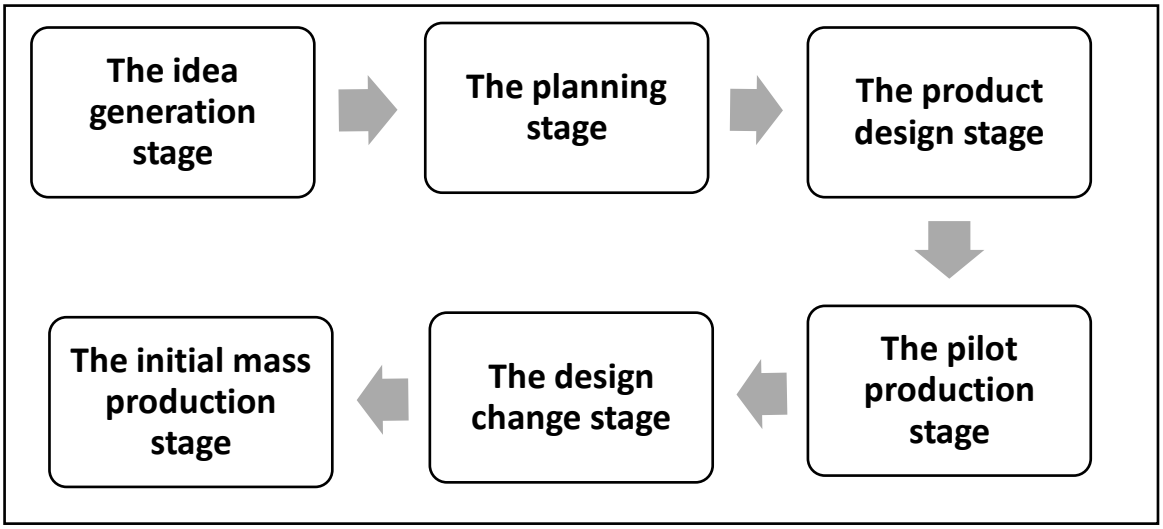
According to **(Gutterman, 2023:5,6)** mention that Wei et al developed a model of five stages for the R&D process—idea generation, planning, design, pilot production and initial production—and described each of them briefly as follows:

a) **The idea generation stage**: Collect potential product concepts and develop formal descriptions and business specifications, considering feasibility and market potential.
b) **The planning stage:** Organise a project team, convert business specifications into engineering specifications, and establish a master schedule, aligning with customer requirements.
c) **The product design stage:**Develop prototypes, produce design output, estimate production costs, and address questions related to standards, manufacturability, and testability.
d) **The pilot production stage**: Construct prototypes, prepare quality control plans, design production flow, and gather input from various departments to prepare for full-scale manufacturing.

e) **The design change stage:** Assess pilot production reports, conduct trial marketing, and incorporate feedback into design decisions, determining the need for further adjustments before mass production.
f) **The initial mass production stage:** Modify production documents, revise equipment and procedures, and rectify materials and drawings to transition from pilot production to full-scale manufacturing efficiently.

These stages represent a systematic approach to developing new products, ensuring thorough evaluation, refinement, and optimisation throughout the R&D process.

Figure (1-3): R&D stages



Source: Made by the Students Based on Previous

1.1.1.5. Research and development Considerations:

Before embarking on the task of research and development, it's crucial for companies and governments to consider some of the key factors associated with it. Some of the most notable considerations are: **(Will Kenton, 2024)**

- **Objectives and Outcome:** One of the most important factors to consider is the intended goals of the R&D project. Is it to innovate and meet a demand for certain products that aren't currently available? Or is it to enhance existing ones? Regardless of the purpose, it's essential to recognize the need for flexibility as circumstances may evolve over time.
- **Timing:** R&D demands significant time investment. This entails assessing the market to identify areas where certain products and services may be lacking or exploring ways to enhance those already available.
- **Cost:** R&D entails substantial financial investment, particularly in terms of initial expenses. Moreover, there may be higher costs associated with the

development and production of new products compared to updating existing ones.

- **Risks:** Like any endeavor, R&D involves risks. There are no guarantees with R&D, regardless of the resources invested. Consequently, companies and governments may jeopardize their (ROI) return on investment if the final product fails to succeed.

1.1.1.6. Importance of Research and development:

Research and Development is crucial for staying competitive in a rapidly changing technological landscape, addressing customer demands, and driving innovation and economic development **(H Erfani, 2019:17)**, R&D is key to:

- **Developing new products and services:** Through R&D, companies can create innovative products that meet changing customer demands and preferences **(Gudda, 2017:147)**.
- **Enhancing competitiveness:** Innovation resulting from R&D can provide a competitive edge in the market, by creating unique offerings that differentiate them from competitors. Continuous innovation through R&D can help businesses maintain market leadership and attract customers . **(Mbukanma & Goswami, 2023:23).**
- **Increasing productivity and efficiency:** R&D can lead to the improvement of existing processes, technologies, and products, making operations more efficient and cost-effective **(Philbin et al., 2022:12).**
- **Societal problems-Solving:** R&D is essential for finding solutions to pressing issues such as health, environment, and energy, thereby improving quality of life **(Mbukanma & Goswami, 2023:23).**
- **Encouraging knowledge expansion:** R&D activities push the boundaries of scientific and technical knowledge, which can be disseminated and applied across various sectors **(Gudda, 2017:147).**
- **Sustaining businesses:** In the context of rapidly evolving markets, particularly after disruptions like the COVID-19 pandemic, R&D helps businesses to adapt and remain relevant by developing new business models and strategies **(Mbukanma & Goswami, 2023:23).**

- In essence, R&D is a key driver behind innovation and long-term success for organizations, industries, and economies **(Kaşik et al., 2016:16).**

1.1.1.7. Research and development Goals:

A goal is the quality or desirable point that an individual or organization is trying to achieve. This goal is determined on the basis of understanding needs, priorities and needs in the individual, organizational and national frameworks, and can therefore be named for some of the goals (R & D). **(H Erfani, 2019:22)**

- Increase community knowledge and culture by invention, initiative and innovation
- Finding potential applications for serious achievements and knowledge
- Satisfaction of human needs, and welfare and comfort
- Increasing the productivity of human activities, which includes increasing incomes.
- Increased self-reliance, along with facilitating and accelerating the conduct of affairs

1.1.1.8. Collaboration with partners and research institutions:

(Un et al, 2010:1) discusses the impact of R&D collaborations on product innovation, highlighting differences in the influence of collaborations with universities, suppliers, customers, and competitors. It suggests that collaborations with suppliers have the highest positive impact, followed by universities, while collaborations with customers have no apparent effect and those with competitors can even harm innovation. Ease of knowledge access seems to be a key factor in driving successful R&D collaborations for innovation.

While **(Fabrise et al, 2015:88)** mention the challenges of university-industry collaboration are explored, Academic researchers acknowledge the increasing value of such collaborations but also note various obstacles, including cultural differences, communication challenges, and differing priorities between academia and industry. These obstacles can hinder the effective transfer of knowledge and technology between the two sectors.

(Patrick Gudda, 2017) in his research aimed to test whether collaboration with partners and research institution technology could affect the product innovativeness of manufacturing SMEs in Kisumu, Kenya. Three predictors (search for new product ideas, externally sourced product/market information, and research institutions' technology transfer) were significant positive predictors of product innovativeness. This implies that collaboration with partners and technology transfer by research institutions enhances SMEs' product innovativeness. Therefore, promoting collaborations with partners and technology transfer by research institutions for the purpose of sharing information and accessing the diverse knowledge base on new product design, development, and production is essential.

So, R&D collaborations significantly boost product innovation, with supplier and university partnerships proving most beneficial. Effective knowledge transfer is key, though university-industry collaborations face cultural and communicative barriers. Promoting collaborations with partners and research institutions enhances SMEs' product innovativeness, highlighting the value of external knowledge and technology transfer.

1.1.1.9.Measuring the effectiveness of R&D

The following table shows the number of frequencies of indicators and dimensions of the R&D as an independent variable in order to choose the most frequent indicators:

Table (1-1): The frequency of indicators and dimensions of the independent variable

Previous studies / Indicators/ dimensions	Gudda (2017)	Tsuji et al (2017)	Benzen, Alaoui (2018)	Amina, Abd_el Wahab (2019)	Meddouki (2019)	Heij et al (2020)	Nadia, Essayeh (2021)	Weiyu, Othman &Guli (2022)	Akinci, Vergil (2022)	Jin& Li (2023)	Henriquez et al , (2023)	Number of repetitions
Partner with other firms	X			X								2
Benchmark	X											1
New product ideas from partners	X											1
External sourcing of market information	X											1
Research partnerships	X											1
Partnership in design/dev/testing	X											1
Technology Factor,		X										1
Human Factors		X										1
cross-functional teams		X										1
quality control (QC) programs		X										1
Information Technology (IT)		X										1
Top Management		X										1
Leadership		X										1
The R&D Expenditure			X	X		X	X		X		X	6
The R&D workers			X				X		X		X	4
Development of new products				X								1
R&D work capabilities					X							1
R&D spending capabilities					X							1

R&D project implementation capabilities					**X**							**1**
Firm size						**X**					**X**	**2**
Firm age						**X**					**X**	**2**
CEO tenure						**X**						**1**
Top management team size						**X**						**1**
Technological acquisition								**X**				**1**
Research and development								**X**				**1**
R&D Intensity									**X**			**1**
Turnover									**X**			**1**
Square of Inflation-Adjusted Turnover									**X**			**1**
Herfindahl-Hirschman Index									**X**			**1**
Industrial Production Index									**X**			**1**
Real Sector Confidence Index									**X**			**1**
R&D capital resources										**X**		**1**
Innovation expenditure per employee											**X**	**1**
Investment opportunities											**X**	**1**
Establishments											**X**	**1**
Foreign											**X**	**1**
Exports											**X**	**1**
Employees											**X**	**1**
Level education											**X**	**1**
Bank financig											**X**	**1**
R&D (Personnel) Intensity											**X**	**1**

Source: Made by the Students Based on Previous studies

Based on the table above we have noticed that the most frequent indicators in previous studies are:

- ✓ **The R&D Expenditure**
- ✓ **The R&D workers**

1.1.1.9.1. Research and development dimensions:

(Valderrama & Mendigorri, 2005:312) define R&D effectiveness as the success in achieving the objectives and results pursued by firms in research and development (R&D) activities. To achieve a comprehensive measurement, they suggest measuring four dimensions: R&D effort, R&D processes, R&D outputs, and R&D performance.

a) **The first dimension, R&D Input**, focuses on measuring the amount and quality of economic, financial, and human resources directed towards R&D activities. The indicator includes factors such as R&D investment,

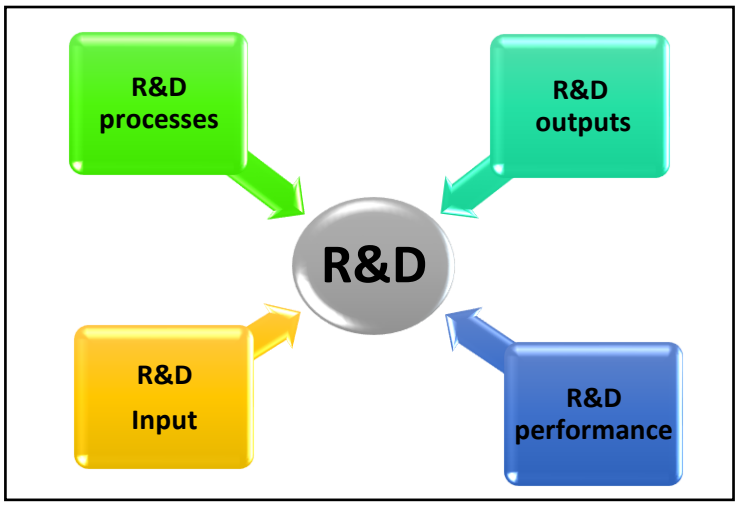
infrastructure use, human resources employed in developing and implementing R&D activities, HR training and experience, HR aptitudes, and the flow of information.

b) **The second dimension**, **R&D processes,** measures the details of the R&D process to identify how it can impact its efficacy and efficiency. Indicators include R&D implementation, the degree of coordination of activities, effectiveness of diversification, involvement of stakeholders, and the influence of external regulation.

c) **The third dimension, R&D outputs,** assesses the direct results of R&D effort. Indicators include innovation in products and processes, achievement of quality, and an increase in profitability.

d) **The fourth dimension, R&D performance,** represents R&D's overall success. Indicators include the quality of the R&D and management techniques used and their innovation, an increase in commercial and financial benefits, and management improvement.

Figure(1-4): The R&D dimensions



Source: Made by the Students Based on Previous

1.1.1.9.2. Research and development indicators:

According to **(Benzene & Alaoui, 2018)** , The function of research and development activities is measured through two important indicators: input index and output index.

a) **The Input Index:** for measuring the function of research and development involves two indicators:

-Proportion of total spending on research and development function: This ratio refers to the value of the total expenses for research and development on the value of sales.

$$\frac{\textit{Overall spending on the function of research and develoment}}{\textit{Total sales value of the institution}}$$

-Proportion of human resources: This percentage refers to the number of active workers in the function of research and development on the total number of enterprise workers.

$$\frac{\textit{The number of active workers in the functions of research and development}}{\textit{The total number of enterprise workers}}$$

b) **The output index:** measures the results of the function of research and development and is measured from two factors:

-The number of patents: granted to the corporation during the period of its activity. The more the institution has a large number of patents, the more it indicates the quality of the completed research and the quality of performance.

-The sales value: of the new product includes the worker. The more the sales value, the more it indicates the effectiveness of R&D activities.

In the document by the **(GYA-IAP-ISC Scoping Group 2023:4)**, it was highlighted that a narrow set of evaluative metrics and indicators do not satisfactorily capture the quality, utility, integrity, and diversity of research.

By implementing strong measurement and evaluation systems that differentiate between research and development activities, and by effectively utilising performance data, organisations can better assess the effectiveness of their R&D efforts. This approach can drive innovation and lead to greater business success.

1.1.2. Technological Innovation :

Numerous studies have focused on technological innovation, and the differences in these studies arise because this topic can be examined from various perspectives. These include an overview of its concept, types, and risks, as well as the indicators for measuring it within an economic institution.

1.1.2.1. Technological Innovation definition:

- **Innovation**:

Innovation is a complex idea, it's what keeps things moving forward in technology and business. There are different ways people define it, each focusing on a different piece of this ever-changing puzzle.

An Austrian economist named **(Schumpeter,1934:65,66)** said innovation is about "doing things in new ways" that lead to companies offering new products, services, or how they get things done. His idea is that innovation can shake things up and totally change the game in a market.

According to **(Rogers, 1962:05)** a big name in sociology, offered a unique take on innovation in his theory of Diffusion of Innovations back in 1962. He described it as something new, like an idea or a gadget, that people or groups start using. His focus was on how people perceive these new things and how they spread within social circles.

The Organisation for Economic Co-operation and Development **(OECD,2005:46),** defines innovation as "the implementation of a new or significantly improved product (good or service), process, marketing method, or organizational method in business practices, workplace organization, or external relations

Through these definitions we can say that innovation is about making changes or improvements to a product, whether it is a specific service or a product.

- **Innovation types:**

(Jain, 2023) outlined various forms of innovation:

- **Product and Service Focus:**

-Product Innovation: Enhancing functionality, design, performance, or packaging of products or services to meet customer needs and introduce new offerings.

-Service Innovation: Developing new or improved services, delivery methods, or customer experiences to enhance value and satisfaction.

- Digital Innovation: Applying digital technologies to create new products, services, or business models.
- Technology Innovation: Utilising new technologies to drive progress and improve outcomes across various fields.
- Computing Innovation: Advancing computing and IT to solve complex problems and enable new capabilities.

- **Process and Operational Focus:**

-Process Innovation: Improving internal processes for greater efficiency, effectiveness, and quality, resulting in cost reduction and increased productivity.
- Incremental Innovation: Making gradual improvements to existing products, services, or processes to stay competitive and relevant.
- Open Innovation: Collaborating with external partners to generate new ideas and co-create innovative solutions.

- **Business Model Focus:**

-Business Model Innovation: Redesigning how an organisation creates, delivers, and captures value through new revenue models, cost structures, and customer engagement strategies.
- Disruptive Innovation: Introducing novel solutions that fundamentally change value creation, delivery, or consumption, often displacing established players.

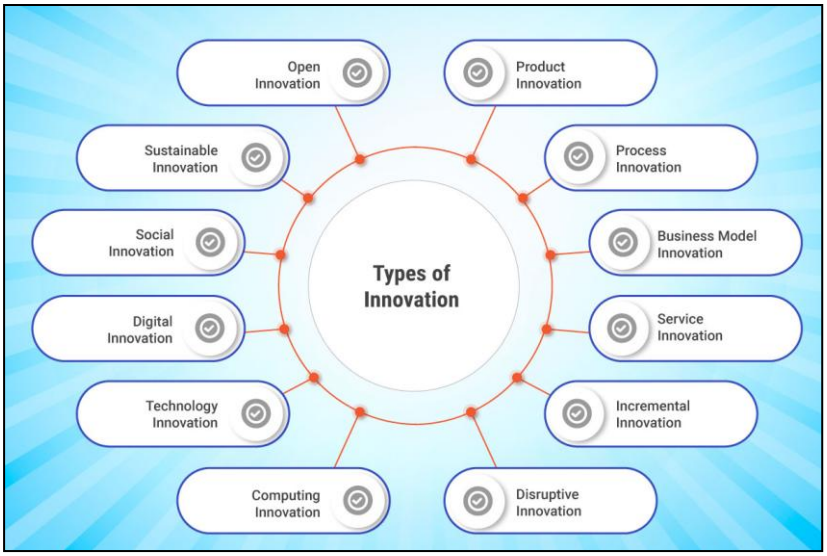
- **Societal and Enviromental Focus:**

- Sustainable Innovation: Developing new products, services, or business models with positive environmental, social, and economic impact.
- Social Innovation: Creating solutions to address social, cultural, economic, or environmental challenges, resulting in positive societal impact.

These various forms of innovation contribute to progress and transformation across industries and sectors.

The following figure shows innovation typs as mentioned in the previous

Figure (1-5): Innovation typs



Source: (Jain,2023)

It must be noted that technological innovation encompasses both product innovation and process innovation. We will discuss technological innovation in the following part, which serves as a dependent variable in our research.

❖ **Technological innovation:**

Technological innovation is an extremely important element, as it is invested by organizations seeking success and wanting to compete in markets at high levels of quantity and quality in various institutional areas. It is therefore important that the individual and the institution are. creative to cope with different changes in the environment. This may pose a threat of collapse and disappearance of institutions that might neglect it and therefore should expand their work and consolidate it as part of their organizational culture. **(Hadjadj, 2015:21)**

Technological innovation is a concept that has been defined in diffrent ways by experts in the field. Understanding its real definition is important to appreciating its role in driving progress and growth within organizations and industries.We can define technological innovation through these visions:

(Schumpeter, 1934:65,66) defines "Technological innovation signifies the continuous and dynamic process of creating, adapting, and exploiting technological advancements and knowledge to catalyze economic development, foster entrepreneurship, and drive structural transformations.

According to **(Freeman, 1974: 18)** Technical innovation or simply innovation is used to describe the introduction and spread of new and improved products and

processes in the economy and technological innovation to describe advances in knowledge"

Defined by **(Dosi, 1982 :1127)** "Technological innovation encompasses the creation and adoption of new technologies, methodologies, or techniques that result in the development of new products, services, or processes, contributing to overall progress and competitiveness.

After these definitions, we can define technological innovation as the creation of something new, as well as the development and improvement of a product or process.

We can present technological innovation through two forms, including:

-Product innovation , which can be the creation of a new product or upgrade an older version

-Process innovation which is the implementation of significantly improved methods for creating or delivering products and services

1.1.2.2 Technological Innovation types:

(Chiffi,Moroni & Zanetti, 2022:05) in their study, they proposed several types or classifications of technological innovation based on the theories of numerous scientists, concluding that, generally speaking, there are four types of technological innovation : Incremental type ,Platform type, Radical type,Frontier technology type.

- **Incremental type :** a simple extension of previously existing technologies in order to satisfy pre-existing societal preferences; in this case, there is quantifable empirical uncertainty and societal preferences pre-date the creation of the new technology.
- **Adaptive type :** technological development in which there are no preexisting societal preferences, but an existing technology may be easily adapted while generating new societal preferences; in this case, there is quantifable .
- **empirical uncertainty :** and societal preferences are created along with the new technology
- **Radical type :** a development of a brand-new technology occurring under severe uncertainty but with clear pre-existing societal preferences to be satisfed; in this case, there is severe empirical uncertainty, and societal preferences pre-date the creation of the new technology.
- **Frontier technology type :** a technology developed in highly uncertain contexts with a clear potential to create a multitude of not-yet-specifed

societal preferences; in this case, there is severe empirical uncertainty, and societal preferences are created together with the new technology.

Through the definitions of **Schumpeter** and **Gosi** and **Freeman** proposed for the concept of technological innovation, it becomes clear to us that there are two main types: product creativity and process creativity.

1.1.2.2.1 product innovation definition:

Product innovation is basically the exciting process of creating fresh ideas or designing something new. This could be a brand new product no one's seen before, or an upgrade to something that already exists, to make people's lives easier or solve problems they might have. here are several definitions of the previous concept:

Schumpeterian View: According to Schumpeter's theory of innovation, product innovation involves the introduction of new products or services that significantly differ from existing offerings, leading to market disruption and economic growth.(**Schumpeter, 1934:65,66)**

Market-Driven View: From a market-driven perspective, product innovation is driven by customer demands and market trends, focusing on creating products that satisfy specific market needs and preferences.**(Cooper, 2011:27)**

Cross-Industry Collaboration View: This perspective emphasizes collaboration between different industries or sectors to leverage knowledge and resources for creating innovative products that transcend traditional boundaries. **(Chesbrough, 2003:43,63)**

From the above, it can be said that product innovation is that new or developed product that be visible to customers.

1.1.2.2.2.Process innovation definition:

Elevating the quality of things is a key part of innovation, especially in research and development. Here are three ways to think about this kind of innovation:

Definition by (**Utterback and Abernathy, 1975:2:11)** Utterback and Abernathy describe process innovation as the development and application of new techniques, equipment, or software to improve production processes and increase operational effectiveness. It encompasses innovations in manufacturing, logistics, and supply chain management.

Definition by **OECD (Organisation for Economic Co-operation and Developmneed:49,50):** According to OECD, process innovation refers to the implementation of new or significantly improved production or delivery methods.

These methods may involve changes in equipment, software, or organizational practices aimed at enhancing efficiency, reducing costs, or improving quality.

Definition by **Tidd and Bessant (2018:22):** Tidd and Bessant define process innovation as the introduction of new methods or systems for producing goods or delivering services. This involves changes in the way tasks are performed, including alterations in workflow, technology utilization, or resource allocation, to achieve enhanced outcomes.

1.1.2.3. Product and process innovation risks :

In terms of risks associated with radical innovation projects within the Fast Moving Consumer Goods (FMCG) sector, **(Keizer & Halman.2009 :504-508)** identifies 12 risk categories that are relevant, while **(Gorobynskaya,2021:4)** he was identified the risks associated with process innovation can be categorized into industrial, environmental, investment, credit, technical, entrepreneurial, financial, and commercial risks .

Table (1-2) : Product and process innovation risks

Products innovation risks	Process innovation risks
1. Product family and brand positioning risks: Concerns about maintaining brand image and market position.	1. **Industrial (production) risks:** Potential damage to the company due to disruptions in the production process.
2. Product technology risks: Challenges in product development, including stability, quality, and production standards.	**2.Environmental risks:** Liability for environmental damage and risks to human health and safety.
3. Manufacturing technology risks: Risks related to production efficiency and effectiveness.	**3. Investment risks:** Risks of reinvestment or loss of profit when implementing investment projects.
4. Intellectual property risks: Threats to protecting patents and trademarks.	**4. Credit risks:** Probability of loan default and non-repayment of interest.
5. Supply chain and sourcing risks: Challenges in securing raw materials and supplies.	**5. Technical risks (construction, installation, and operational risks):** Associated with building new facilities and their ongoing operation.

6. Consumer acceptance and marketing risks: Concerns about meeting consumer preferences and marketing success.	**6. Entrepreneurial risks:** Challenges arising from negative external circumstances and difficulties in organising production and sales.
7. Trade customer risks: Risks associated with meeting trade customer demands and supply chain management.	**7. Financial risks (currency, interest, portfolio):** Risks encountered in managing enterprise finances.
8. Competitor risks: Threats from industry competitors impacting market share.	**8. Commercial risks:** Risks associated with trading operations and conducting business transactions.
9. Commercial viability risks: Economic and financial concerns regarding product profitability.	
10. Organisation and project management risks: Challenges in managing innovation projects internally.	
11. External risks: Risks from external factors such as political, legal, and technological changes.	
12. Screening and appraisal risks: Risks in assessing project feasibility and market potential.	

Source: Made by the Students Based on refrences

This summary provides a concise overview of the various product innovation risks within the FMCG sector

1.1.2.4 Indicators to measure technological innovation:

The following table shows the number of frequencies of indicators and dimensions of the technological innovation as a dependent variable in order to choose the most frequent indicators:

Table (1-3): The frequency of indicators and dimensions of the dependent variable

Previous studies / Indicators/ dimensions	Patrick Gudda (2017)	Tsuji et al (2017)	Benzen, Alaoui (2018)	Amina, Abd_el Wahab (2019)	Meddouki (2019)	Heij et al (2020)	Nadia, Essayeh (2021)	Weiyu, Othman &Guli (2022)	AKINCI, VERGİL (2022)	Jin& Li (2023)	Henriquez et al , (2023)	Number of repetitions
Product innovation	X	X				X			X		X	5
the number of patents			X							X		2
sales volume			X									1
development of new products				X								1
R&D capabilities					X							1
absorptive capabilities					X							1
manufacturing capabilities					X							1
marketing capabilities					X							1
organizing capabilities					X							1
linkage capabilities					X							1
Management innovation						X						1
Environmental dynamism						X						1
Firm performance						X						1
Industrial firms						X						1
New product design							X					1
Improve current product							X					1
innovation investment								X				1
Attitude toward didgital innovation								X				1
technological culture								X				1
Process Innovation									X		X	2

Source: Made by the Students Based on Previous studies

Based on the table above we have noticed that the most frequent indicators in previous studies are:

- ✓ **Number of patents**
- ✓ **Product innovation**
- ✓ **Process innovation**

Technological innovation indicators provide valuable insights into the progress, effectiveness, and potential outcomes of research and development (R&D) activities aimed at driving technological advancement. We can categorize these indicators into tree main dimensions: **(Taques, F. H., López, M. G., Basso, L. F., & Areal, N. 2021:6 ,8).**

a) Input Indicators:

- R&D Expenditure: Investment in R&D activities is a primary input indicator, highlighting the financial resources dedicated to innovation.

-Human Resources: The number and expertise of personnel involved in innovation activities, including scientists, engineers, and technical staff.

-Technology Investment: Funds allocated for acquiring and implementing new technologies, machinery, and infrastructure.

b) Throughput (Process) Indicators:

-Patents Filed: The number of patents applied for or granted is an important throughput indicator, reflecting ongoing innovative activities.

-Collaborations and Partnerships: The extent and quality of collaborations with other organizations, universities, and research institutions.

-Development Milestones: Progress in innovation projects, such as reaching prototype development, pilot testing, or achieving specific research goals.

Process Improvements: Implementation of new or improved processes, methods, or techniques that enhance productivity or efficiency.

c) Output Indicators:

-New Products/Services: The number of new or significantly improved products or services introduced to the market.

-Market Performance: Metrics such as sales growth, market share, and revenue generated from new products or services.

-Customer Satisfaction: Customer feedback, adoption rates, and satisfaction levels with the new innovations.

-Economic Impact: Broader economic benefits such as job creation, productivity improvements, and contributions to GDP.

These signs, taken all together, give us a solid picture of how well research and development (R&D) is working. We can see if it's really driving innovation in companies and whole industries.

1.1.3. Relation between R&D and technological innovation:

The relationship between Research and Development (R&D) and technological innovation is pivotal in modern business strategy, particularly within science and

technology sectors. Here are the key points outlining this relationship: **(Gilbert et al, 2018: Xiv)**

- **Competitive advantage (Added value):**

- Innovation, especially technological innovation, is increasingly strategic for businesses.
- Technological innovation is central to developing competitive advantages and is crucial for business survival.
- Technological innovations may include new processes, products or services that bring added value compared to existing solutions and offers.

- **Customer focus:**

- Innovation helps meet customer renewal expectations.
- It addresses the rapid obsolescence of products due to technological advancements and competitors' strategies.

- **Product and Process(Re-engineering):**

- In science and technology-driven industries, R&D is essential for product and process innovation.
- R&D is a major player in the innovation process, positioned high on the agenda of firms competing through intensive innovation.
- Opening and pursuing new research avenues internally.
- Developing new technical solutions and improvements.
- Coordinating and ensuring the technical development of innovations.

- **Knowledge development:**

- R&D develops new scientific and technical knowledge.
- This knowledge is used to design technological innovations

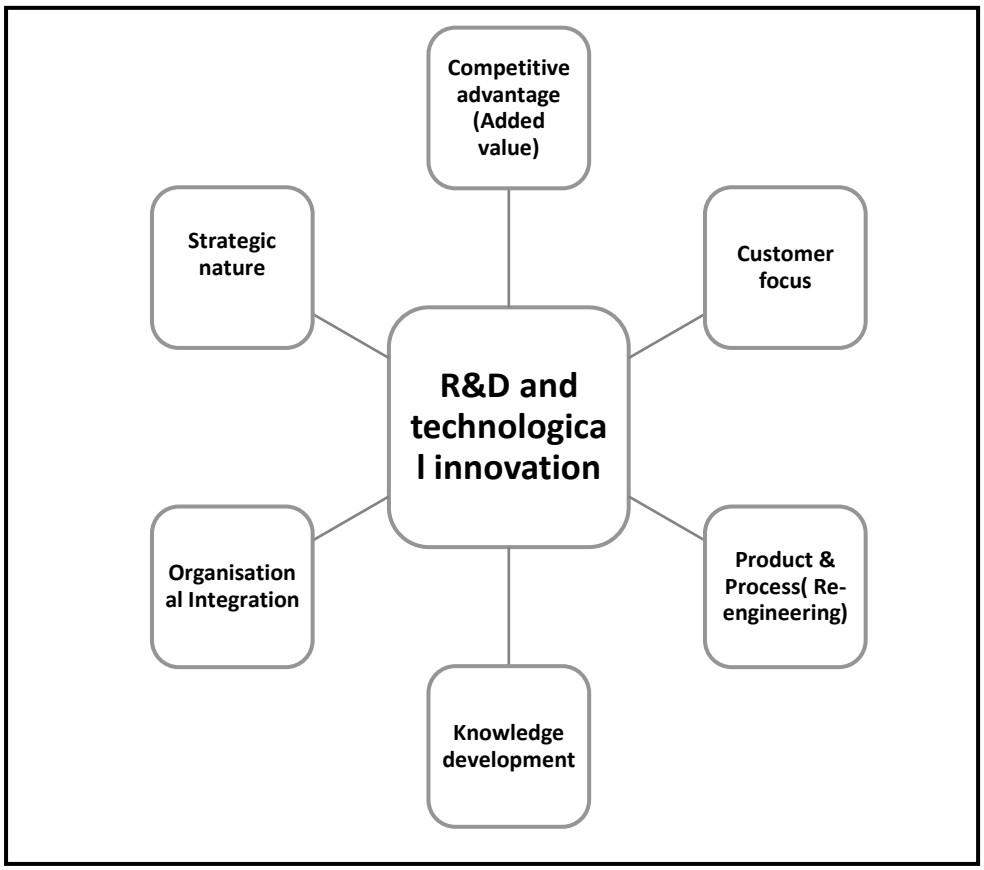
- **Organisational Integration:**

- R&D can be distributed across the company or centralised in a specific unit.
- Distributed R&D involves experts, engineers, and scientists within production or technical support services.
- Centralised R&D involves a specialised unit with diverse specialist teams dedicated to R&D activities.

- **Strategic nature :**

- R&D drives and initiates technological innovation.
- It holds a privileged position in strategic planning alongside other functions like marketing, production, and procurement.

Figure(1-6): The relationship between variables



Source: Made by the Students Based on Previous

Overall, R&D is fundamental in fostering technological innovation, ensuring that companies not only stay competitive but also lead in their respective industries. This strategic integration highlights the importance of continuous investment and focus on R&D for sustained technological advancement and market relevance.

1.2. Emperical studies of The Role of Research and Development in achieving Technological Innovation

1.2.1.Presenting previous studies:

1.2.1.1.Arabic studies:

The first Arabic study chosen, titled **"The Impact of Research and Development on the Quality of New Products: A Case Study of the Research and Development Centre at the Sidal Complex",** was authored by **(Amina, Abd_Elwahab 2019)**. Its aim was to determine the facts and test the impact of research and development (R&D) using three indicators: investment in R&D activities, collaboration with external partners, and development of new products. The study aimed to access new high-quality products by conducting field research at the Research and Development Centre of SIDAL. The problem addressed was: How can the Research and Development Centre at the Saidal Complex follow an approach based on research and development that enables it to access new products of high quality to compete at the local and global levels? The study employed the interview method with experts and decision-makers and utilised both descriptive and analytical methodologies.

The results indicated that research and development drive increased innovation as the primary source of new products. Additionally, research and development is portrayed as a creative and organised function that enriches knowledge reservoirs, improves performance methodologies, and delivers rapid and direct results.

The authors of this study focus solely on new products as the dependent variable, which is one type of technological innovation.

The second study chosen, entitled **"The Impact of Research and Development Capabilities and Technological Innovation Capabilities on the Creative Performance of Industrial Institutions: A Study of a Group of Institutions in the Electronic and Home Electrical Industry Sector in Algeria"** by **(Meddouki, 2019)**, aims to identify R&D capabilities using indicators such as R&D worker capabilities, R&D spending capabilities, and R&D project implementation capabilities. It also explores technological innovation capabilities using indicators including R&D, absorptive, manufacturing, marketing, organising, and linkage capabilities. The study investigates their impact on innovation performance indicators such as product innovation, process innovation, and sales performance within the electronic and home-appliance industry in Algeria. The research question addressed is: What is the impact of research and development capabilities and technological innovation

capabilities on the innovative performance of the electronic and home electrical industry institutions under study in Algeria?

The study utilised a descriptive method to analyse data collected through the distribution of 230 questionnaires among employees of 6 private enterprises, particularly those in the Research and Development, Production, and Marketing departments. A total of 189 responses were received.

The findings indicate that R&D project implementation capabilities do not significantly impact innovation performance. Regarding technological innovation capabilities, only R&D capabilities affect product innovation performance.

This study adopts a broad perspective of technological innovation, encompassing organising and marketing in addition to technological innovation.

In their study **(Nadia Essayeh, 2021)**, titled **"The Role of Research and Development Activities in Activating the Product's Technological Creativity: A Field Study of a Sample of Industrial Sector Enterprises in Algeria during (2017-2020),"** the authors explore the impact of research and development (R&D) activities on technological creativity in product development. The study utilises indicators such as expenditure and employment to assess R&D activities and their influence on new product design and improvement of current products in the Algerian industrial sector. The Problem that was raised is: "At what extent do research and development activities contribute to activating technological innovation of the product in the industrial institutions under study in Algeria?".The study used 80 questionnaires distributed among employees, particularly those in research and development and production departments.

The results highlight the importance of prioritising R&D activities, as they play a crucial role in enhancing technological innovation in products. This requires consistent allocation of resources and ongoing evaluation of outcomes. The authors emphasise the necessity of maintaining adequate financial support for R&D in industrial institutions, necessitating careful advance planning.

The authors used both types of technological innovation - new product development and improvement of current products - in their study.

1.2.1.2.Foreign studies :

The first foreign study chosen was that of **"R&D and non-R&D in the innovation process among firms in ASEAN countries"**, authored by **(Tsuji et al, 2017)**. The study aimed to identify factors promoting innovation in the framework of R&D based on surveys conducted on firms in five ASEAN countries: Indonesia, Laos, Thailand, the Philippines, and Vietnam. The study divides sample firms into two categories: the "R&D group" and the "non-R&D group." By categorising firms in this manner, the analysis seeks to differentiate

the innovation processes between these two groups and identify the factors that drive product innovation within each group. The study employs Ordered Probit Analysis as the methodological approach to examine the factors influencing innovation within R&D and non-R&D groups.
The results suggest that R&D and non-R&D groups operate under almost entirely different processes for product innovation; R&D groups tend to promote innovation through formal R&D activities, cross-functional teams, and learning processes, while non-R&D groups rely more on informal leadership and top management experience.
This study was about both R&D and non-R&D firms, and the authors focus on innovation generally while the way of applying innovation is different for each one. This differentiation underscores the need for tailored innovation strategies and policies.

Another study conducted by **(Patrick Gudda, 2017)** that bears the title **" The role of research institutions in product innovativeness among manufacturing Small and Medium Enterprises (SMEs) in Kisumu Town, Kenya"**, aimed to investigate the role of research institutions in enhancing product innovativeness among manufacturing Small and Medium Enterprises (SMEs) in Kisumu Town, Kenya. Utilising a sample size of 126 manufacturing SMEs registered and licensed within Kisumu town, the study employed a cross-sectional survey design to collect data through questionnaires and observation guides. The study focused on the firm level, analysing the impact of collaboration with partners, search for new product ideas, externally sourced product/market information and research institutions technology transfer on product innovativeness among SMEs in Kisumu. A logistic regression model with six predictors was used to analyse the data.

The study found that collaboration with partners and technology transfer by research institutions had a significant positive effect on product innovativeness among manufacturing SMEs in Kisumu. Factors such as searching for new product ideas, externally sourced product/market information, and research institution technology transfer were identified as significant predictors of product innovativeness. The results highlighted the importance of partnerships and knowledge transfer from research institutions in enhancing SMEs' innovation capabilities.

In this study, the author focuses on small and medium enterprises and used only product innovation as a dependent variable while used research institutions as independent variable instead of R&D.

Another study titled: **"The impact and function of research and development on the activity of oil companies: Study the case of France's Total compound for the period 2015"** was by **(Benzene and Alaoui, 2018)**. It aimed to investigate the impact of research and development (R&D) activity on the performance of petroleum enterprises during the period between 2011 and 2015. France's Total was chosen as the compound to test the variables of the study. The researchers measured R&D activity using input and output indexes. The input index included the company's spending on R&D and the ratio of R&D workers to total workers. The output index comprised the number of patents obtained by the company and sales volume.

The study concluded that research and development had a significant impact on the activity of TOTAL Foundation. The findings indicated that the size of incomes and the number of patents increased year after year, highlighting the positive influence of R&D activity on the company's performance.

Activity of companies used in this study as an independent variable instead of technological innovation.

Also, **(Heij et al, 2020)** in their research: **"How to leverage the impact of R&D on product innovation? The moderating effect of management innovation"**, aimed to improve the focus on the relationship between R&D effectiveness, management innovation, and product innovation within firms. It highlights the importance of understanding how management innovation can enhance the impact of R&D by using its indicators: Investment in R&D, Firm size, Firm age, CEO tenure, Top management team size, on product innovation by using its indicators: Management innovation, Product innovation, Environmental dynamism, Firm performance, Industrial firms (dummy variable). Randomly selected a sample of 10,000 companies from a commercial database containing information on companies registered with the Dutch Chamber of Commerce. The sample covered a broad range of industries and was restricted to firms with at least 25 employees. It ended up with 901 observations, 171 of which were removed, so 730 observations used for the analysis.

The findings show that the relationship between R&D and product innovation varies with differing levels of both R&D and management innovation. Firms that focus solely on increasing either management innovation or R&D especially small and medium-sized firms (SMEs) utilise new technological knowledge to a lesser extent. These findings imply that firms which pursue more product innovation by investing mainly in more R&D will achieve suboptimal outcomes in terms of product innovation. If firms increase their levels of both R&D and management

innovation, at a certain point the complementary effects between the two activities mean that product innovation will improve. In the initial stages, however, they may experience a temporary reduction in product innovation.

This study uses management innovation as a medium variable and its effect to enhance the impact of R&D.

(Akinci, & Vergil, 2022) have also made an effort in their study: **"Effect of R&D on product and process innovation in the Turkish manufacturing industry"**, aimed to examine the effect of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation in the Turkish manufacturing industry, classified by NACE Rev.2 (the statistical classification of economic activities in the European Community). The study utilises panel data by making sub-breakdowns of R&D variables between 2009 and 2016, sourced from various micro datasets obtained from surveys conducted by TURKSTAT. The probit model was used in the panel data analysis. The study used R&D expenditure, R&D intensity as indicators of R&D. Additionally, total R&D expenditure is separated into four breakdowns such as internal, external, external-domestic, and external-foreign, and the same separation was used for total R&D intensity and other indicators such as R&D (Personnel) Intensity, Turnover, Square of Inflation-Adjusted Turnover, Herfindahl-Hirschman Index, Number of R&D Personnel, Industrial Production Index, and Real Sector Confidence Index.

The results indicate that the effects of R&D expenditure on product and process innovations vary by its sub-breakdowns. Total and internal R&D expenditure have a positive effect on both product and process innovations, while external and external-domestic R&D expenditure have a positive effect only on product innovation, and external-foreign R&D expenditure only on process innovation. Only external, external-domestic, and external-foreign R&D intensity have a positive effect on both product and process innovation.

This study used both types of technological innovation as independent variables. While the impact of R&D was different depending on which sub-breakdown had more effect on Product or process or affected both of them.

Additionally, **(Weiyu, Othman & Guli, 2022),** titled: **"Role of Technological Acquisition and R&D Expenditure in Innovative Investment"**, aimed to explore the relationship between technological acquisition, research and development (R&D) expenditure, and innovative investment. A quantitative research design was employed in the present study by expressing the variables of the study in numbers and analysing the relationships hypothesised in the study through statistical methods. A deductive approach was used to confirm the

hypotheses of the study that were established to investigate the effect of independent variables on the dependent variables. The study collected data from 341 employees in the R&D department of the corporate sector in China.

Results of the study showed a significant relationship between the independent variables (technological acquisition and R&D) and the dependent variables (innovative investment and attitude toward digital innovation). The study also found that attitude toward digital innovation among the employees positively and significantly impacted innovative investment. Moreover, attitude toward digital innovation acts as a partial mediator between technological acquisition and innovative investment, and R&D and innovative investment.

This study pointed out that technology is one of the important sources to achieve innovation in corporations.

Recently, **(Henriquez et al, 2023)** have shown concern towards the topic in their research: **"Impact of R&D on the Innovation of Products and Processes in Latin Countries"**. They investigate the impact of Research and Development (R&D) investment on product and process innovations. Due to a lack of data availability, its study is difficult to address in emerging markets, so the researchers used microdata from 5588 firms in different Latin American countries to examine the relationship between R&D investment and the impact on innovation outcomes. To achieve the objectives of this study, they used machine learning methodology and compared its results to a traditional innovation model. The CDM model, through autonomous learning, eliminated irrelevant variables and incorporated two joint innovation variables: innovation development and innovation expenditure per number of employees. This approach allowed for a more accurate analysis by focusing on variables most relevant to the adjustment objective.

The research findings indicated that R&D investments have a positive effect on both process and product innovation in Latin American firms. These results contribute to the existing literature on R&D and innovation within companies and have significant implications for public policy and firm strategies.

This study used R&D as an independent variable and Innovation of Products and Processes as a dependent variable; both variables are used in the current study.

Another recent study by **(Jin & Li, 2023)**, titled: **"Study on the impact of R&D input intensity on technological innovation output – Based on data from China's technology industry"**, focuses on analysing the impact of different sources of R&D capital investment on technological innovation output in China's

high-tech industries from 2009 to 2020. The study measures the intensity of R&D investment from various channels, including enterprises' capital, government capital, foreign capital, and other sources. The following hypothesis was formulated: The increase in the intensity of enterprises' capital investment positively impacts innovation output by generating a financial "reservoir" effect to support R&D innovation. By using a Panel Vector Autoregression (PVAR) model, the study employs STATA16 statistical software to analyse the data and draw conclusions based on the results obtained from the PVAR model. The research empirically tests the effects of R&D investment intensity from each channel on innovation output.

The results showed that the increase in enterprises' own capital investment intensity and government capital investment intensity has a positive effect on innovation output. This is attributed to the financial support provided by these investments for R&D activities. While Foreign capital investment intensity and other capital investment intensity show a neutral impact on innovation output at the current stage.

This study focuses on the importance of financial support from enterprises and governments in driving technological advancements.

1.2.2. Copmaring between current study and previous studies:

In this part, We will try to show similarities and differences between the current study and the previous studies that were listed above.

Table (1-4): Copmaring between current study and previous studies

	Current study	Previous studies
The variabls used	Research and development as independent variable , technnological innovation as dependent variable.	All previous studies used R&D as independent variable,in other hand most of studies used either technological innovation as dependent variable or one of his typs or both.
The research approach	Descriptive and Analytical approaches	Studies varied between use Descriptive, Quantitive and Analytical approach

Tools	The company's website, Its Annual reports and statstical websites	Most of studies relied on the questionnaire as a tool for collecting data and information.
The sector	Petroleum Sector	Primarily focus on industrial and economic sectors such as the hight technology and petroleum industries
Goals	aims to determine the relationship between research and development and technological innovation	aimed in general to improve the understanding of the relation ship between R&D inputs and innvation outcomes.

Source: Made by the Students Based on Previous studies

1.2.3. The contribution of previous studies :

Previous studies have significantly contributed to constructing the theoretical framework and helped in choosing the study's variables . Also guided in building hypotheses. Moreover, these studies have helpful in identifying and justifying the most appropriate methodology for the study and presenting dimensions and indicators of these studies have driven to choose suitable indicators.

1.2.4. Characteristics of the current study:

What distinguishes the current study from previous studies is its focus on the petroleum sector, unlike prior research which concentrated on various different sectors, with the exception of the study by Benzene and Alaoui (2018). The study's inputs were indicators that reflect real data. Additionally, the period of this study encompassed the time before the COVID-19 pandemic, during the pandemic, and after it.

Summary of chapter:

In this chapter, literature review and empirical studies related to the study variables has been presented. Starting with a section that provided a conceptual framework dealing with different sides of the concepts R&D and technological innovation including; definitions, importance, types, dimensions, risks…. Concerning previous studies, it has been pointed at and exposed in the second section, building on prior studies it has been cleared that there has been an interest in the role of research and development in achieving technological innovation has been studied from different point of views. These studies have been summarized and then compared to the current study, and as a result, findings were similar and agreed in some points, however, differed in some. The relationship between the two of variables will be tested through the field study in chapter two.

Chapter two

Field study of the Role of Research and Development in achieving Technological Innovation

Preface:

After illustrating literature review and empirical studies for Research and development and Technological Innovation, we also exposing previous studies that dealt with the same topic, summarizing, and comparing them with the study in hand. This chapter will be concerned with the Field study of Shlumberger Company, in order to explore the reality of research and development and the role of R&D in achievingtechnological innovation. And which we will demonstrate in details through the following two sections:

- **Section one:** Method and Study tools
- **Section two:** Results and Discussion

2.1. Method and research tools

We are going to explain the method we have used in the case study to collect information and data.

2.1.1.Research Method:

- To achieve the desired goals of the research, we considered a descriptive approach appropriate. This approach was utilised in the literature review, relying on books, articles, PhD dissertations, and websites to gather information and data about the research variables.
- An analytical approach was also employed in the field study to explore the relationship between variables, using company websites, annual reports, and statistical websites, the **Microsoft Excel Programme** used for processing the data.

2.1.2 Research tools:

In our research, we will work to study the role of R&D activity on technological innovation at SLB company in the period from 2010 to 2022, a period during which we will seek to address the problem posed in this study by utilising variable indicators based on annual reports as well as a selection of statistical websites.

2.1.3. Research Variables and its indicators:

Variables of the study are demonstrated in the following **Table (2-1).**

Table (2-1): Study variables

Variables	indicators
independent variable	R&D expenditure
	R&D employees
dependent variable	Number of patents
	Product and process innovation

Source: made by the students

2.1.4. Study population

SLB, a leading global provider of technology for reservoir characterisation, drilling, production, and processing to the oil and gas industry, serves as the study population for this dissertation.

SLB was chosen due to its significant impact on the oil and gas industry and its extensive use of innovative technologies, making it an ideal case for examining R&D and technological innovation in energy exploration.

We will discuss the origin and evolution of SLB, followed by an examination of its organisational structure and R&D within the company.(We obtained this information (Definition, organizational characteristics, R&D department) the company's official website , https://www.slb.com/).

2.1.4.1.SLB company definition:

Schlumberger (now known as SLB) is an International Technical Company providing products and services specialising in oilfield and drilling technology. It was founded in 1927 by brothers Conrad and Marcel SLB, who were French engineers. The SLB brothers were pioneers in the development of geophysical exploration techniques.

The journey began in 1912 when two brothers, Marcel and Conrad SLB, conducted laboratory tests on the electrical resistivity of "oil-bearing rocks" based on geophysical formulas to determine the lithology of various subsoils. Fifteen years later, in 1927, they applied the results of their research in an actual oil well for the Pechelbronn Oil Company, revolutionising the oil and gas industry.

SLB is a privately funded company listed on the New York Stock Exchange (NYSE) since 1962. Its shares are traded under the symbol "SLB," with over 34.11 billion dollars in revenue from operations in 2024, ranking it as the second-largest oilfield services company in the world, behind its direct competitor Halliburton Energy Services (HES). SLB has its main offices in Houston for Oilfield Services and in Paris for Development and Research (SRPC). The company started its operations in Europe and later expanded to become a global entity operating in more than 120 countries **(Appendix 1)**, including Algeria, and employs over 111,000 people in 2023 from 140 different nationalities. Olivier Le Peuch is the chief executive officer of SLB, a position he has held since August 2019.

Over time, SLB has diversified its activities and has become virtually the leader in each of the following three sectors:

- Oilfield Services

- Integrated Project Management

- SLB Information Services.

2.1.4.2. Organizational characteristics:

SLB company is a leading global oilfield services company that provides technology for reservoir characterisation, drilling, production, and processing to the oil and gas industry. Its structure is organised as follows:

- **Board of Directors:** Provides overall governance and strategic direction.
- **Executive Management:** Led by the CEO, this team manages the company's operations and strategic initiatives.
- **Global Operations:** Divided into various geographic regions, each managed by regional executives to cater to local markets and operations.
- **Product Lines and Segments:** SLB is divided into several product lines and segments, including:
  - **Reservoir Characterisation Group:** This group focuses on understanding and evaluating subsurface reservoirs
  - **Drilling Group:** This group is responsible for all aspects of drilling operations.
  - **Production Group:** This group focuses on enhancing and optimising production from reservoirs
  - **Cameron Group:** focuses on products and services for the oil and gas industry
- **Functional areas:**
  - **Research & Development (R&D):** Focuses on research and development (R&D), engineering, and the creation of new technologies and solutions to enhance oil and gas exploration, production, and processing.
  - **Sales and Marketing:** Responsible for promoting Schlumberger's products and services and securing contracts with clients worldwide.
  - **Operations:** Manages the day-to-day execution of projects, ensuring safety, efficiency, and client satisfaction.
  - **Supply Chain and Logistics:** Manages procurement, inventory, transportation, and distribution of materials and equipment required for operations.
  - **Health, Safety, and Environment (HSE):** Ensures the safety of employees, contractors, and the environment through rigorous HSE policies, practices, and training programs.
  - **Human Resources:** Focuses on talent acquisition, development, and retention.
  - **Finance:** Manages the company's financial health, including budgeting, forecasting, and reporting.
  - **Legal and Compliance:** Ensures that the company adheres to legal standards and regulatory requirements.

2.1.4.3. R&D department in SLB company:

The Research and Development (R&D) department at SLBis pivotal in driving innovation through the creation of new technologies and improving existing products and processes.

The R&D department is responsible for conducting extensive research, developing new products, enhancing existing technologies, and ensuring the company remains at the forefront of technological advancements in the oil and gas industry.

The R&D department focuses on:

- **Innovation:** Developing new technologies and improving existing ones to enhance the efficiency and safety of oil and gas exploration and production.
- **Technical Excellence:** Ensuring that SLBstays at the forefront of technological advancements in the industry.
- **Sustainability:** Creating solutions that reduce environmental impact and enhance sustainability in operations.
- **Collaboration:** Working closely with academic institutions, industry partners, and internal teams to drive forward-thinking projects and initiatives.

The R&D function is integral to SLB's success, as it drives the technological advancements that enable the company to maintain a competitive edge in the oil and gas industry. This function supports the development of innovative solutions that address complex challenges in reservoir characterisation, drilling, production, and processing.

2.2. Results and Discussion

2.2.1. Results of the research:

Depends measuring function of research and development on two indicators input index includes total spending on R&D activity, as well as on the number of workers R&D activity of the total number of workers.

2.2.1.1. R&D indicators:

a) R&D expenditure:

The following table presents the R&D expenditure at SLB company from 2010 to 2022.

Table(2-2): The R & D activity Expenditure according to Total expenditure during the period from the year 2010-2022

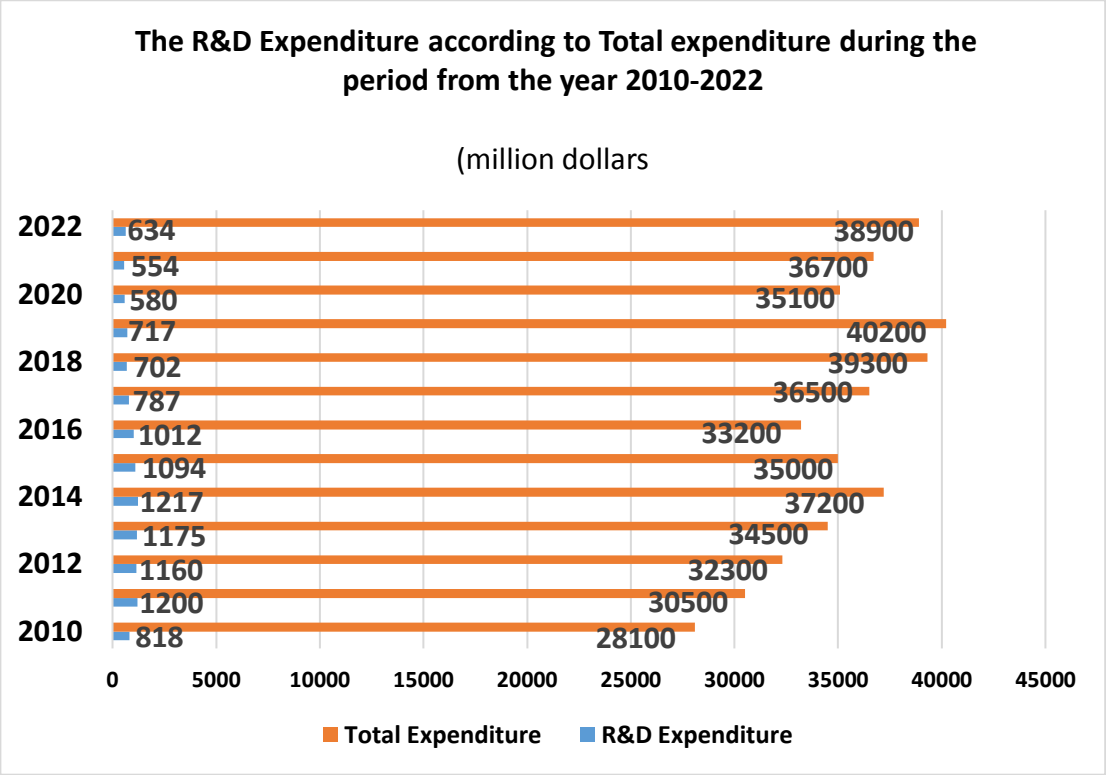
Years	R&D Expenditure (million dollars)	Total Expenditure (million dollars)	The ratio%
2010	818	28100	2.91
2011	1200	30500	3.93
2012	1160	32300	3.59
2013	1175	34500	3.41
2014	1217	37200	3.27
2015	1094	35000	3.13
2016	1012	33200	3.05
2017	787	36500	2.16
2018	702	39300	1.79
2019	717	40200	1.78
2020	580	35100	1.65
2021	554	36700	1.51
2022	634	38900	1.63
Highest value	**1217**	**40200**	**3.93**
Lowest value	**554**	**28100**	**1.51**
Mean	**970.83**	**38125**	**2.55**

Source: Made by the Students Based on :

- https://investorcenter.slb.com/financials/annual-reports-proxies
- https://finbox.com/NYSE:SLB/explorer/rd_exp/

The previous **table (2-2)** shows SLB's R&D expenditure as a percentage of total expenditure from 2010 to 2022, from 2010 to 2014, SLB maintained a relatively high level of R&D expenditure, consistently above 3%. The peak was in 2011 at 3.93%. The ratio shows a gradual decline from 3.13% in 2015 to 2.16% in 2017. From 2018 onwards, the R&D expenditure as a percentage of total expenditure dropped significantly, reaching its lowest point at 1.51% in 2021. In 2022, there was a slight increase in the R&D expenditure ratio to 1.63%.

Figure (2-1): The R&D Expenditure according to Total expenditure during the period from the year 2010-2022



Source: Made by the students based on Excel output

The figure (2-2) illustrates SLB's R&D expenditure in relation to its total expenditure from 2010 to 2022. It highlights a peak in R&D spending at 1217 million dollars in 2014 with a growth of 48.78% according to the year 2010, and a gradual decline to 554 million dollars by 2021, followed by a slight recovery to 634 million dollars in 2022.

b) R&D workers:

The following table presents the number of R&D emplyees at SLB company from 2010 to 2022.

Table (2-3): The R&D employees according to Total employees during the period from the year 2010-2022

Years	R&D Employees	Total Employees	The ratio%
2010	5800	108000	5.37
2011	6000	113000	5.31
2012	4000	118000	3.39
2013	3600	123000	2.93

2014	6000	120000	5
2015	3000	95000	3.16
2016	3700	100000	3.70
2017	3000	100000	3
2018	3800	100000	3.80
2019	3500	105000	3.33
2020	4400	86000	5.12
2021	3600	92000	3.91
2022	4500	99000	4.55
Highest number	**6000**	**123000**	**5.37**
Lowest number	**3000**	**86000**	**2.93**
Mean	**4575**	**113250**	**4.04**

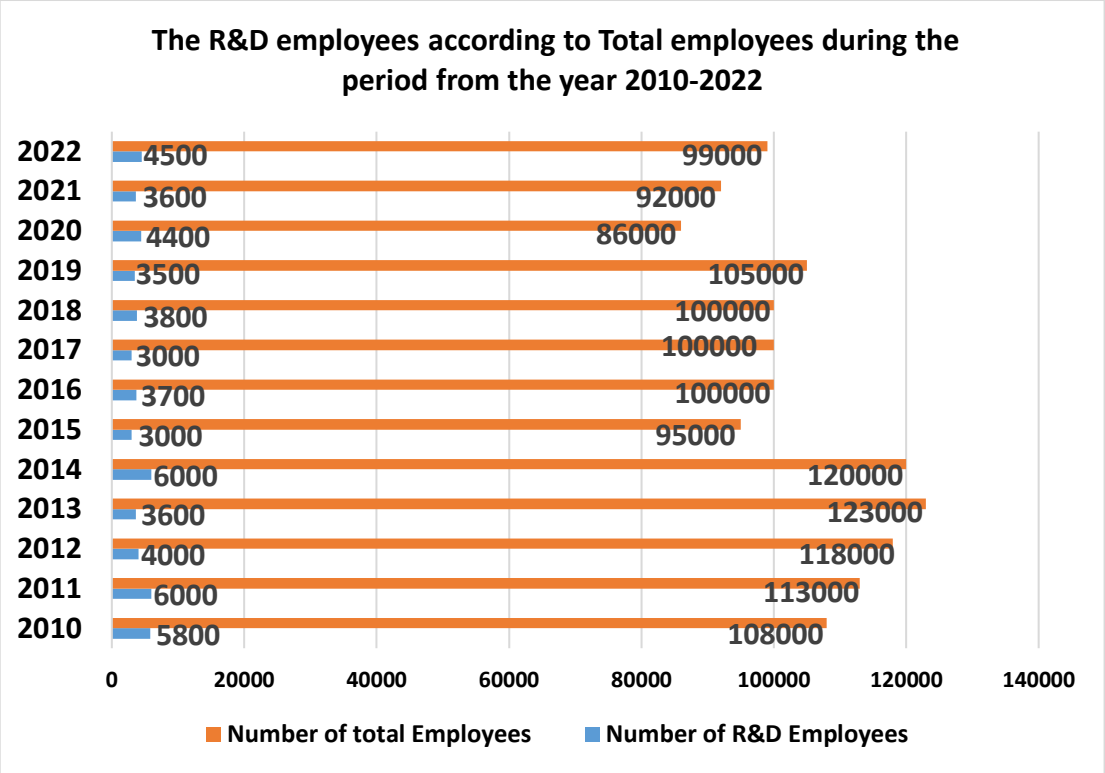
Source: Made by the students based on :

- https://stockanalysis.com/stocks/slb/employees/
- https://investorcenter.slb.com/financials/annual-reports-proxies

According to the previous **table (2-3)**, SLB's R&D employees, as a percentage of total employees of the company in the period 2010-2022, were as follows:

The ratios in 2010 and 2011 were relatively high, above 5%, indicating a strong emphasis on R&D. However, there was a notable decline starting in 2012, reaching a low of 2.93% in 2013. The ratio rebounded to 5% in 2014. However, this was followed by another decline, hitting a low of 3% in 2017. From 2018 onwards, the ratio saw a gradual recovery, peaking again at 5.12% in 2020. This increase during 2020, while there is a slight decrease to 3.91% in 2021, followed by a rise to 4.55% in 2022.

Figure (2-2): The R&D employees according to Total employees during the period from the year 2010-2022



Source: Made by the Students Based on Excel output

The figure (2-3) illustrates the number of R&D employees compared to the total number of employees at SLB company from 2010 to 2022. R&D employee numbers peaked at 6000 in 2011 and 2014 pointed to a growth of 3.45% according to the year 2010, while total employee numbers reached their highest at 125,000 in 2014. Following this peak, both R&D and total employee numbers declined significantly, reaching lows in 2017. The figure shows a recovery in R&D staffing to 4500 by 2022.

2.2.1.2.Technological innovation indicators

a) Number of new patents:

Table (2-4): The number of patents during the period from the year 2010-2022

Years	Number of patents		
	SLB Compnay	Halliburton company	Baker Hughes Company
2010	465	268	362
2011	451	227	334
2012	463	270	370

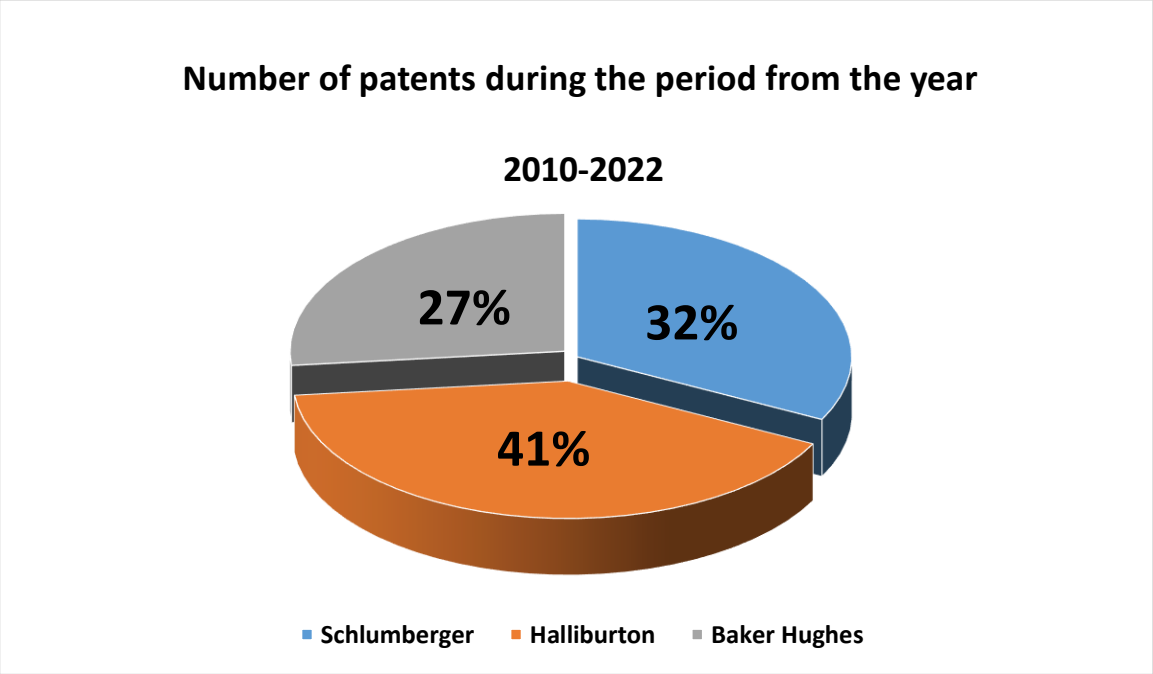
2013	507	368	368
2014	506	430	422
2015	454	464	484
2016	448	549	408
2017	432	738	452
2018	626	806	344
2019	589	1020	429
2020	425	771	342
2021	435	882	394
2022	372	963	350
Highest number	**626**	**1020**	**484**
Lowest number	**372**	**227**	**334**
Mean	**514.42**	**646.33**	**421.58**

Source: Made by the Students Based on:

- https://www.patentdocs.org/
- https://www.uspto.gov/
- https://ipo.org/
- https://houston.innovationmap.com/

The table (2-4) presents the number of patents filed by SLB Company, Halliburton Company, and Baker Hughes Company from 2010 to 2022. Halliburton consistently leads in the number of patents, reaching a peak of 1020 in 2019 with a growth of 280.59 % according to the year 2010, and an arithmetic mean of 646.33 patents per year. SLB Company follows, showing a more stable trend with a peak of 626 patents in 2018 with a growth of 34.62% according to the year 2010, and an arithmetic mean of 514.42 patents per year. Baker Hughes Company has the lowest patent counts among the three, peaking at 484 in both 2014 and 2015 with a growth of 33.70% according to the year 2010, with an arithmetic mean of 421.58 patents per year. The data indicate Halliburton's stronger emphasis on innovation through patents, followed by SLB and Baker Hughes.

Figure (2-3): Number of patents during the period from the year 2010-2022



Source: Made by the students based on Excel output

The pie chart and **Figure (2-4)** illustrates the distribution of patents among SLB, Halliburton, and Baker Hughes companies from 2010 to 2022. Halliburton holds the largest share with 41% of the total patents, SLB follows with 32%, indicating a strong but slightly lesser emphasis on patenting new technologies. Baker Hughes accounts for 27% of the patents, the smallest share among the three companies.

b) Products and processes innovation:

The following table shows the number of innovative products and processes developed by SLB Company

Table (2-5) :SLB's new products and processes from 2010 to 2022

Year	Type	Name and description
2010	**Product**	▪ **AquaPerm SM:** Analysis of geological formations to improve extraction efficiency. ▪ **Signature Quartz gauges :** High-accuracy downhole pressure and temperature measurement**.** ▪ **PowerDrive Archer :**

		Improved directional drilling system. ▪ **PURE :** High-temperature electric submersible pump for geothermal applications.
2011	**Product**	▪ **REDA HotlineSA3 ESP System :** temperature electric submersible pump for geothermal applications**.** ▪ **SonicScope 475 Service:** High-definition logging-while-drilling service. ▪ **IntelliZone Compact System:** Modular multizonal management system.
2012	**Product**	▪ **Saturn 3D Radial Probe |** Enhanced fluid sampling ▪ **Signature Quartz Gauges & PowerDrive Archer** Award-winning drilling and measuremen
	Process	▪ **SLB China Petroleum Institute** Advanced research and technology collaboration in China.
2013	**Product**	▪ **Vx Spectra Flowmete**r Accurate multiphase flow rate measurement. ▪ **MicroScope HD Service** High-definition imaging while drilling.
2014	**Product**	▪ **PowerDrive Orbit RSS** Improved directional drilling system. ▪ **Updated Software Platforms** Enhanced multidisciplinary integration in exploration and production.
2015	**Product**	▪ **Infinity Dissolvable Plug-and-Perf System** Fully degradable fracture balls and seats.
	Process	▪ **Integration with Cameron** Merging surface and subsurface technologies.
2016	**Product**	▪ **GyroSphere MEMS Service** Advanced gyro-while-drilling service.
2017	**Service**	▪ **DELFI Cognitive E&P Environment** Cloud-based platform for E&P workflows.
2018	**Product**	▪ **Gaia Data Discovery Platform** Access to E&P data and AI tools.
2019	**Product**	▪ **Ora Wireline Testing Platform** Advanced formation testing.
2020	**Product**	▪ **NeoSteer At-Bit System** Integrated bit and steering functionalities for drilling.

2021	**Product**	▪ **Autonomous Directional Drilling** Automated drilling system
2022	**Product**	▪ **Transition Technologies Portfolio** Technologies to reduce carbon footprint.

Source: Made by the students based on SLB website

Previous **table (2-5)** above shows that during the period from 2010 to 2022, SLB company consistently demonstrated innovation through the development of advanced products and processes, enhancing operational efficiency, precision, and sustainability in the oilfield services sector. Notable product innovations include **the AquaPerm SM in 2010** for improved extraction efficiency, **the high-definition SonicScope 475 in 2011**, and the automated **Autonomous Directional Drilling system in 2021**. Process innovations such as **the integration with Cameron in 2015** reflect strategic mergers to combine surface and subsurface technologies. The 2022 introduction of the **Transition Technologies Portfolio** highlights SLB's commitment to reducing the carbon footprint, aligning with global sustainability goals. This timeline underscores SLB's adaptive approach to technological advancement.

2.2.2. Analysis of the results

a) R&D Expenditure on the number of patents:

The following results were taken from the table(2-2) which shows research and development expenditure, and the table (2-4) which shows the number of patents

- **High R&D Expenditure Period (2010-2014):**The R&D expenditure was relatively high, peaking at 1217 million dollars in 2014 and accounting for 3.27% of the total. While the number of patents filed ranged from approximately 451 to 507 during this period.
- Despite fluctuations in R&D spending, the number of patents filed remained stable. This stability was attributed to strong market conditions as the oil and gas industry experienced high commodity prices and robust demand **(Appendix 2)**, resulting in increased revenues for SLB **(Appendix 3)**. This financial stability allowed SLB to prioritise innovation and maintain a competitive advantage through substantial R&D investment. This suggests robust innovation that effectively translated R&D efforts into patented technologies.
- **Moderate to Declining R&D Expenditure (2015-2017):** R&D spending decreased from 1094 million dollars in 2015 (3.13% of the total) to 787 million dollars in 2017 (2.16%).The number of patents filed also saw a slight decline, from around 454 in 2015 to 432 in 2017.

- The decrease in R&D expenditure correlated with a minor drop in patent filings, although the impact was not directly proportional. This decline was attributed to the significant drop in oil prices starting in late 2014 **(Appendix 2)**, which led to reduced revenues for oilfield services companies, including SLB **(Appendix 3)**. This financial pressure necessitated budget cuts, including in R&D. However, SLB's existing innovation and past investments helped mitigate the decline.

- **Low R&D Expenditure with Patent Spike (2018-2019):** R&D expenditure continued to decrease, reaching 702 million dollars in 2018 (1.79% of the total) and slightly increasing to 717 million dollars in 2019 (1.78%), albeit at a reduced rate. Despite this decrease in spending, there was a significant spike in patents in 2018 (626 patents), followed by a high number in 2019 (589 patents).

- Persistently low oil prices and industry challenges **(Appendix 2)** kept R&D budgets constrained . This led to low R&D expenditure, while the spike in patents despite lower spending can be attributed to the fact that innovations often take years to develop. The high number of patents reflects the maturation of projects initiated during periods of higher R&D investment, indicating a time lag between R&D investments and their innovation outputs, as well as improved R&D productivity.

- **Recovery Period (2020-2022):** R&D spending was at its lowest in 2020 (580 million dollars) took a percentage 1.65% of the total, but showed a recovery to 634 million dollars in 2022 (1.63% of the total). Meanwhile, the number of patents decreased from 425 in 2020 to 372 in 2022.

- The decline in R&D budgets in 2020 was attributed to the global pandemic COVID-19, which led to unprecedented economic disruptions, impacting oil demand and prices **(Appendix 2)**. SLB's revenues and budgets **(Appendix 3)**, including R&D, were further strained. However, as the industry began to recover, SLB started to reinvest in R&D, albeit at a measured pace due to ongoing financial constraints. The decline in patents during this period reflects the cumulative effects of reduced R&D budgets, and it will take time for recovery efforts to translate into increased innovation outputs.

According to above there is a relationship between R&D expenditure and the number of patents filed.

b) R&D Expenditure on product and process innovation:

The following results were taken from the table (2-2) which shows spending on research and development, and the table (2-5) which shows product and Process innovations

- **High R&D Expenditure and Product Innovations (2010-2014):** The R&D spending was relatively high, peaking at 1217 million dollars in 2014 (3.27% of the total). During these years, SLB introduced significant product and process innovations like **PowerDrive Archer**, **PURE**, **IntelliZone Compact System, SLB China Petroleum Institute.**
- The high investment in R&D matched high oil prices **(Appendix 2-2)**, which increased demand for oilfield services and technology, leading SLB to invest more in R&D such as collaboration with Petroleum Institute in China. The company's focus on technological leadership also contributed to major product launches, showing a direct link between substantial R&D funding and product innovation.
- **Moderate to Declining R&D Expenditure (2015-2017):**The R&D spending decreased from 1094 million dollars in 2015 (3.13% of the total) to 787 million dollars in 2017 (2.16 of the total) . Despite this, there were still notable product and process innovations, like **Infinity Dissolvable Plug-and-Perf System, DELFI Cognitive E&P Environment service** and the **Integration with Cameron.**
- SLB maintained its innovation activities even with lower R&D spending. The fall in oil prices **(Appendix 2-2)** led to cost-saving measures, reducing R&D expenditure and focusing only on key innovations that could provide substantial value.
- **Low R&D Expenditure and Innovation Efficiency (2018-2022):**R&D expenditure continued to decrease, hitting its lowest at 554 million dollars in 2021 (1.51% of the total) before slightly recovering to 634 million dollars in 2022 (1.63% of the total). Despite this, significant innovations like the **Gaia Data Discovery Platform** and the N**eoSteer At-Bit System** were introduced, indicating efficient use of R&D funds.
- Continued low oil prices **(Appendix 2-2)** required further reductions in R&D budgets **(Appendix 3)**, leading SLB to make efficient use of limited funds and focus on high-impact projects that align with industry trends in digital transformation and sustainability.

According to above there is a clear relationship between R&D expenditure and the rate of product and process innovations.

c) R&D employees on the number of patents:

The following results were taken from the table (2-3) which shows research and development employees and the table (2-4) which shows the number of patents

- **High R&D Employee Numbers (2010-2011 and 2014):** During 2010-2011 and 2014, the number of R&D employees was quite high, reaching 6000 in 2011 (5.31% of the total) and 2014 (5% of the total). In these years, the number of patents filed ranged from 451 to 506.
- A high number of R&D employees is linked with a stable and relatively high number of patents. This is due to significant investment in innovation driven by the oil and gas industry's need for advanced technologies. More employees led to more patents.
- **Drop in R&D Employees (2012-2013):** There was a notable decrease in R&D employees to 4000 in 2012 accounting for 3.39% of the total and 3600 in 2013 (2.93% of the total). Despite this reduction, the number of patents increased to 463 in 2012 and 507 in 2013.
- The increase in patents, despite having fewer employees, suggests improved efficiency through better technology and automation. This allowed fewer employees to produce more patents by focusing on important projects.
- **Significant Reduction and Recovery (2015-2022):** The number of R&D employees fluctuated, hitting a low of 3000 in 2015 (3.16% of the total) and 2017 accounting for 3% of the total , and recovering to 4500 in 2022(4.55% of the total). The number of patents also varied, with a peak of 626 in 2018 and a decline to 372 in 2022.
- The low number of R&D staff in 2015 and 2017 was due to the oil price crash and industry downturn **(Appendix 2)**, leading to cost-cutting measures. The peak in patents in 2018 was due to a focus on operational efficiency. By 2022, the recovery of R&D employees to 4500 suggests a reinvestment in innovation and growth. However, the decline in patents to 372 in 2022 indicates a shift towards more strategic, targeted innovation rather than focusing on quantity.

According to above there is a relationship between the number of R&D employees and the number of patents filed.

d) R&D employees on product and process innovation:

The following results were taken from the table (2-3), which show research and development employees and the table (2-5) which shows Process and product innovations

- **High R&D Employees (2010-2011, 2014):** The number of R&D employees was 5800 in 2010 accounting for 5.37% of the total,and 6000 in 2011(5.31%

of the total) and 2014(5% of the total). During these years, multiple innovative products were introduced, such as **AquaPerm SM, Signature Quartz gauges, REDA HotlineSA3 ESP System**, and **PowerDrive Orbit RSS** .

- High numbers of R&D employees led to significant innovations, driven by the company's strategic investment in technology to improve oil recovery and efficiency. These innovations were crucial for meeting the growing demand for more efficient and reliable energy extraction methods, justifying the increased investment in R&D personnel

- **Decrease in R&D Employees (2012-2013):** The number of employees reduced to 4000 in 2012 (3.93% of the total) and 3600 in 2013(2.93% of the total). Despite this, important products like the **Saturn 3D Radial Probe, Vx Spectra Flowmeter** were still introduced, and Process like **SLB China Petroleum Institute.**

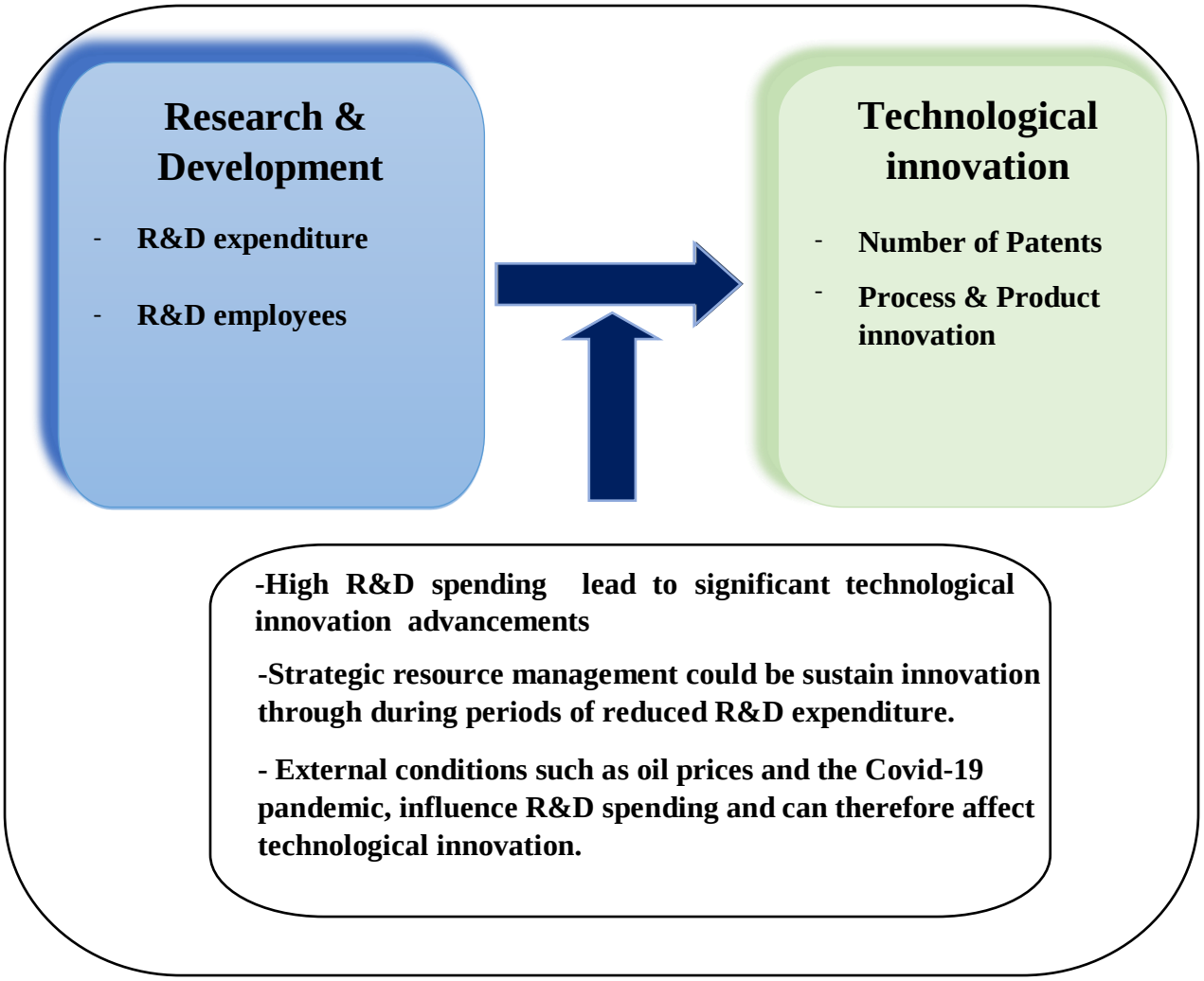
- Even with fewer R&D employees, significant innovations continued. This reduction was part of a broader initiative to streamline operations and cut costs. By keeping the most skilled and productive employees, the company maintained high levels of innovation with a smaller R&D team. This move was a part of strategic plan for expansion through investment in advanced research and technology collaboration in China.

- **Fluctuations and Recovery (2015-2022):** The number of employees fluctuated, hitting a low of 3000 in 2015(3.16% of the total) and 2017 accounting for 3.% of the total, and recovering to 4500 in 2022 (4.55% to the total). Key innovations during this time included the **Infinity Dissolvable Plug-and-Perf System, DELFI Cognitive E&P Environment**, and the **Transition Technologies Portfolio.**

- The sharp decline in employees to 3000 in 2015 and 2017 was due to a severe downturn in oil prices **(Appendix 2)**, leading to cost-cutting and workforce reductions. Despite these cuts, the company focused on high-impact innovations that required fewer but highly skilled personnel. The recovery in R&D staff by 2022 shows renewed investment in R&D as market conditions improved, especially after the impacts of the Covid-19 pandemic, allowing the company to expand its innovation capacity and continue developing advanced technologies crucial for future growth and industry leadership.

The comparison reveals a relationship between the number of R&D employees and the introduction of product and process innovations.

Figure (2-4): Results' summarizing



Source: Made by the students based on previous

2.2.3. Results' discussion and comparation to previous studies:

Based on the findings, in this section, we will discuss the results of hypothesis testing for SLB's R&D and technological innovation:

Hypothesis 1: There is a high level of R&D activity at SLB company.

- SLB's R&D expenditure has been substantial over the years, averaging 970.83 million dollars per year from 2010 to 2022., peaking at $1217 million in 2014 and maintaining significant investments even during economic downturns, with $634 million in 2022.
- The company employed a considerable number of R&D staff, peaking at 6000 in 2011 and 2014, with an average of 4575 R&D employees per year.

The results strongly support the hypothesis that there is a high level of R&D activity at SLB company.

Previous result agree with the study by **(Amina, Abd_Elwahab,2019)**, and the study by **(Nadia Essayeh, 2021)**.

Hypothesis 2: There is a high level of technological innovation at SLB company.

- SLB company consistently filed a substantial number of patents annually, averaging 514.42 patents per year from 2010 to 2022, with a peak of 626 patents in 2018.
- The company introduced numerous innovative products and services, such as the **AquaPerm SM** (2010), **PowerDrive Archer** (2010), **DELFI Cognitive E&P Environment** (2017), and **Transition Technologies Portfolio** (2022).
- Notable process innovations include the **strategic integration with Cameron** in 2015 and the establishment of the **Schlumberger China Petroleum Institute** in 2012.

The results clearly indicate a high level of technological innovation at Schlumberger, supporting the hypothesis.

Previous result agree with the study by **(Amina, Abd_Elwahab,2019),** and with the study by **(Heij et al, 2020).**

Hypothesis 3: There is a relationship between independent variable R&D and dependent variable technological innovation.

- High R&D expenditure years, such as 2010-2014, correlate with significant patent output and product introductions. The peak R&D expenditure in 2014 aligns with numerous innovations in subsequent years.
- The number of R&D employees also shows a relationship with patent numbers and product and process innovations. Peaks in R&D staff numbers (2011 and 2014) align with high patent outputs and significant product launches.
- During periods of reduced R&D expenditure, such as 2017-2021, SLB maintained technological innovation, indicating effective R&D management and strategy.
- Previous results demonstrate a clear relationship between R&D investments, both in terms of expenditure and employees, and technological innovation at SLB company.

The results suggest a strong relationship between R&D efforts (both expenditure and employees) and technological innovation (both of patents, products and process innovation) at SLB, validating the hypothesis.

Previous result agree with study by **(Nadia Essayeh, 2021),** and the study by **(Patrick Gudda, 2017),** and partially disagree with study by **(Meddouki, 2019)**, as it found that R&D capabilities alone do not drive innovation performance, which contradicts the direct relationship proposed in our study.

Summary of chapter:

This chapter focused on the field study and was divided into two sections. The first section began with an introduction to the company under study (SLB), followed by an explanation of its Organizational characteristics and the R&D function targeted for the study. We then gathered information from the company's official website and relied on its annual reports, through which we analyzed and processed the data. The second section presented all the results obtained from the data analysis and concluded with testing the hypotheses and discussing the results in comparison with previous studies' findings.

Conclusion

Conclusion:

In this thesis, we attempted to shed light on how R&D can have a significant impact on technological innovation at SLB, particularly from 2010 to 2022. We relied on the company's official website and annual reports to collect data and used the descriptive-analytical method to analyze and interpret the results as a measurement tool. In the first chapter, we covered the literature review of both variables, R&D (R&D employees, R&D investment and spending) and technological innovation (New product process and services, patents) and studied the indicators of each variable. To provide further enrichment, we presented some previous studies that addressed the same topic, focusing mainly on R&D and technological innovation.In the second chapter, we applied a practical study through a field study on SLB to understand the reality of R&D in the company and the level of technological innovation.

a) Results of the Study:

Through this study, we arrived at several conclusions, which are as follows:

- ✓ SLB's sustained focus on R&D is a key driver of its technological innovation.
- ✓ High R&D spending has historically led to significant product and process advancements, while strategic management of R&D resources during economic downturns has enabled continued innovation.
- ✓ SLB's ability to sustain innovation during periods of reduced R&D expenditure through strategic resource management highlights the importance of R&D in maintaining technological leadership in the oilfield services industry.
- ✓ The correlation between R&D investments and technological outputs underscores the vital role of R&D in maintaining SLB's leadership and adaptability in the oilfield services industry.
- ✓ External conditions such as oil prices and the Covid-19 pandemic, influence R&D spending and can therefore affect technological innovation.

b) Hypotheses Test:

Discussion the results hypothesis testing for SLB's R&D and technological innovation based on the findings:

Hypothesis 1: There is a high level of R&D activity at SLB company.

- ➢ SLB's R&D expenditure has been substantial over the years, averaging 970.83 million dollars per year from 2010 to 2022., peaking at $1217 million in 2014 and maintaining significant investments even during economic downturns, with $634 million in 2022.

- The company employed a considerable number of R&D staff, peaking at 6000 in 2011 and 2014, with an average of 4575 R&D employees per year.

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- The number of R&D employees also shows a relationship with patent numbers and product innovations. Peaks in R&D staff numbers (2011 and 2014) align with high patent outputs and significant product launches.
- During periods of reduced R&D expenditure, such as 2017-2021, SLB maintained technological innovation, indicating effective R&D management and strategy.
- Previous results demonstrate a clear relationship between R&D investments, both in terms of expenditure and employees, and technological innovation at SLB company.

The results suggest a strong relationship between R&D efforts (both expenditure and employees) and technological innovation (both of patents, products and process innovation) at SLB, validating the hypothesis.

Previous result agree with study of **(Nadia Essayeh, 2021),** and study of **(Patrick Gudda, 2017),** and partially disagrees with study' result of **(Meddouki, 2019)**, as it found that R&D capabilities alone do not drive innovation performance, which contradicts the direct relationship proposed in our study.

c) Suggestions:

- Increase Investment in R&D by Financial commitment to R&D can drive innovation, improve product quality, and maintain competitive advantage.
- Enhance Collaboration with External Partners such as universities, research institutions, and other companies in order to provide access to new knowledge, technologies, and resources that can significantly boost innovation.
- Focus on Developing R&D Capabilities by Investing in training and development of R&D Highly efficient employees. Enhance their skills and capabilities which contribute to technological innovation.
- Implement agile methodologies in R&D projects to increase flexibility and responsiveness to market changes.
- Create an organizational culture that values creativity and innovation. Encourage employees to experiment, take calculated risks, and learn from failures.
- Implement AI and machine learning tools to enhance research capabilities, automate routine tasks, and accelerate innovation processes.

d) Further research:

- The effect of digital innovation on R&D products
- The effect of digital technologies on R&D process.
- The impact of research and development outputs in enhancing sustainable competitive advantage.
- The role of human capital in enhancing research and development capabilities.

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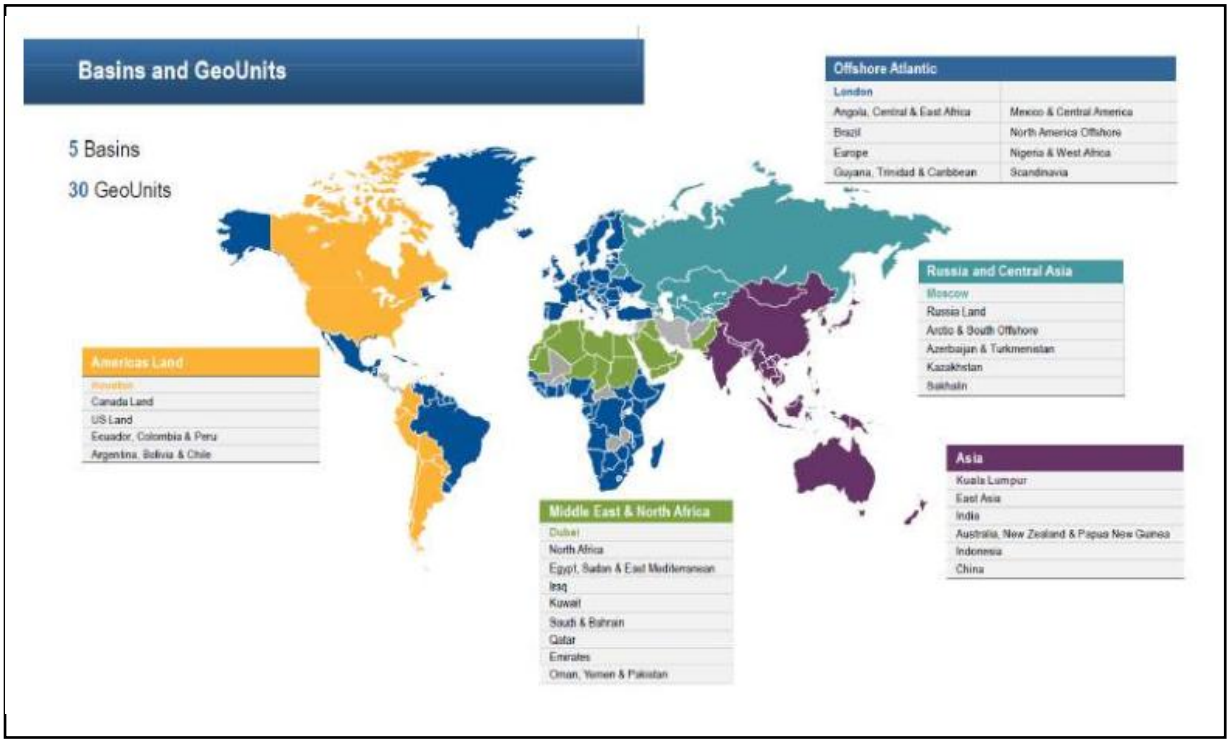
Appendices

Appendix (1): SLB in the worldwide



Source: (Sami et al, 2021)

Appendix (2): Oil prices during period (2010-2022)

Years	Oil prices (Billion Dollars)	
2010	77.38	-
2011	107.46	↗
2012	109.45	↗
2013	105.87	↘
2014	96.29	↘
2015	49.49	↘
2016	40.76	↘
2017	52.51	↗
2018	69.78	↗
2019	64.04	↘
2020	41.47	↘
2021	69.89	↗
2022	100.08	↗

Source: Made by students based on:
https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

Appendix (1): Revenues of SLB during period (2010-2022)

Years	Revenues (Billion Dollars)	
2010	27.45	-
2011	39.54	↗
2012	41.73	↗
2013	45.27	↗
2014	48.58	↗
2015	35.47	↘
2016	27.81	↘
2017	30.44	↗
2018	32.82	↗
2019	32.92	↗
2020	23.60	↘
2021	22.93	↘
2022	28.10	↗

Source: SLB Annual Reports

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