EXPLORING STRATEGIC PERSPECTIVES OF NUCLEAR POWER MANAGEMENT IN INDIA

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by

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DECLARATION

I Bhuvan Bhardwaj hereby certify that the work which is being presented in the project report entitled "Exploring Strategic Perspectives of Nuclear Power Management in India" in partial fulfillment of the requirements for the award of the degree of Masters of Business Administration (Executive) in Data Science and Analytics, submitted in the University School of Management & Entrepreneurship, Delhi Technological University is an authentic record of my own work carried out during the period from May'2025 to July'2025 under the supervision of Prof. Manoj Kumar Sharma.

The matter presented in the project report has not been submitted by me for award of any other degree of this or any other institute.

Name: Bhuvan Bhardwaj

Roll No: 23/UEMBA/03

CERTIFICATE BY THE SUPERVISOR

Certified that Bhuvan Bhardwaj (Roll No. 23/UEMBA/03) has carried out their search work presented in this project report titled “Exploring Strategic Perspectives Of Nuclear Power Management in India” for the award of Masters of Business Administration (Executive) Data Science and Analytics from University School of Management and Entrepreneurship, Delhi Technological University, under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the project report do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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ABSTRACT

The Nuclear Power Industry in India has recently witnessed a significant push as part of India's long term energy transition strategy. Nuclear Power is the world's second-largest source of low-emissions electricity. This study aims to provide a comprehensive strategic analysis of the Indian Nuclear Power Sector. The research evaluates the historical achievements, current status, competitive positioning and identifying critical factors for shaping the competitive advantage of industry.

The research has been carried out by application of Michael Porter's Diamond Theory of National Advantage. Analysis work is carried out where the Diamond components (*Demand Conditions, Factor Conditions, Related and Supporting Industries, Firm Structure, Strategy and Rivalry, Role of Government and Chance)* are identified and working of the Diamond is analysed.

The study identifies the components of Porter's Diamond model, *Firm Structure, Strategy, and Rivalry* are not present; *Related and Supporting Industries* and the *Role of Government* are weakly present; while *Demand Conditions, Factor Conditions,* and *Chance* are adequately present. The analysis further concludes that due to these gaps, the Diamond model does not function effectively in India's Nuclear Power Industry.

The findings indicate that India's Nuclear Power Industry derives its competitiveness primarily from favourable Factor conditions, such as the availability of skilled human resources, as well as positive Demand conditions and Chance events like the clean energy transition and the emergence of small modular reactors. However, the industry continues to face significant challenges due to the absence of Domestic Competition, the lack of benefits from competitive Supporting Industries, and an inadequate and fragmented role of the Government. In summary, the analysis suggests that Porter's Diamond framework is partly functioning for India's Nuclear Power Sector, resulting in only a limited competitive advantage under the current circumstances.

Recently Government of India has taken some key initiatives to support the Indian Nuclear Power sector. These includes considering amendments to Atomic Energy Act to open Sector to Private and Foreign Players, Limiting the Liability in case of Damage to suppliers, Setting aggressive target of 100 GW Nuclear Power by 2047, Technology Transfer, R&D Funds for Small Modular Reactors. Based on the Analysis of this study, steps taken by the Government are in the right direction and will help to improve the competitiveness of Nuclear Power Industry in upcoming years.

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LIST OF ABREVIATIONS

NPCIL	Nuclear Power Corporation of India Limited
DAE	Department of Atomic Energy
AEC	Atomic Energy Commission
TIFR	Tata Institute of Fundamental Research
HBR	Harvard Business Review
SMR	Small Modular Reactors
BARC	Bhabha Atomic Research Centre
NTPC	National Thermal Power Corporation
IOCL	Indian Oil Corporation Limited

CHAPTER 1: INTRODUCTION

Nuclear Power is the world's second-largest source of low-emissions electricity. There are considerable studies carried out about India's nuclear programme, yet there are very few studies that focus on India's Nuclear Power industry. An ideal industry is required with well-designed infrastructure, secured reactors and sound technical knowhow, without which electricity cannot be generated. The researcher has decided to study about the competitiveness of India's Nuclear Power industry which will make India's nuclear programme more viable and as well as profitable.

An industry can be analysed in many ways such as how the industry operates, what are the raw materials used, who are the major players, what is their performance, what is the current state of the industry, what is the future growth potential, what are the major problems faced by the industry, what is the technological level and support required from the Government, who are the end users, what are the expectations of the users etc. which are called as "nature or characterises" studies of an industry.

Nuclear Power Industry

Nuclear Power industry of India is one of the unique, peculiar industries and India started working on Nuclear Power just after Independence.On 23rd March 1948, Prime Minister Jawaharlal Nehru introduced the Atomic Energy Bill in the Indian Parliament, and it was subsequently passed as the Indian Atomic Energy Act. Construction of first Nuclear Power Plant at Tarapur started in 1964. Considering the various challenges of Power from Fossil Fuel Power Plants and their impact on environment, Nuclear Power being clean is considered as a good alternative to base load requirements for electric grid stability. Moreover Government of India has set an ambitious target of 100 GW of Nuclear Power by 2047 and mulling legislative changes to make more conducive environment for the industry.Hence, the researcher felt it is more important to assess the competitiveness of Nuclear Power industry.

The word competitiveness can be defined as the quality or ability of being as good as or better than others of a comparable nature. According to World Economic Forum, competitiveness is the set of institutions, policies and factors that determine the level of productivity of a country [1].Competitiveness can also be defined as the ability of a country or region or location to deliver the beyond – GDP (gross domestic product) goals for its citizens [2]. According to Michael Porter, competitiveness is must for an industry and the need to be competitive is listed out as follows.

- An industry can continue to operate and function only when it is competitive. When the industry is not competitive, others will take over it and its very existence is threatened.
- Capacity of the industry to develop from current state to next state is based on its competitiveness.
- Ability of the industry to witness growth is entirely dependent on its competitiveness. Better the competitiveness higher the ability to grow.
- Achieving competitiveness is not a destination but it is a way of life. The industry can be competitive currently, but if the industry does not uphold its competitiveness, the industry will face survival threat in the future. [3]

Theory Used for the Study

The term competitiveness when mentioned brings in comparison. It compares the ability to perform based on certain pre-determined qualities and it is time bound. This comparison need not necessarily between two parties or two industries. The competitiveness can be assessed for a particular industry also. While assessing the competitiveness, quality of the parameters used for assessment is very crucial. Detailed, unbiased, objective and time tested qualities must be used here. The reason being, these qualities ensure reliable results.

Hence the researcher uses “Competitive Advantage of Nations - Diamond Model” for assessing the competitiveness of Indian Nuclear Power industry. This model has been developed by Michael E Porter. [4]

CHAPTER 2: OBJECTIVE OF STUDY

The researcher in this study is focussing on following key objectives for Indian Nuclear Power Industry:

- Assess the competitiveness of India's Nuclear Power industry using Diamond Model.

- Identify strength, weakness and key areas of improvement for growth of Nuclear Power Industry in India

The researcher works in the Nuclear power Industry and has interacted with various professionals of the Nuclear Power industry. The researcher was immensely benefited to formulate his core objective of the project. All the input received from nuclear industry experts had become as his primary source.

During the course of the study the researcher had reviewed many online articles, books, journals about his area of research and form the secondary source for this research.

CHAPTER 3: LITERATURE REVIEW

Nuclear Industry of the World

The aggregate of manufacturing/technically productive enterprises in a particular field, often named after its principal product are called as an industry. To give example, automobile industry or steel industry comes under this meaning. Secondly with the development of service sector, activities under service category also called as industry, software industry, hospitality industry comes under this meaning. Thirdly any general business activity or commercial enterprise is also called as industry; to give example for this meaning Indian tourist industry can be quoted. In general, trade or manufacture is called as industry. Fourthly the ownership and management of companies, factories are also refereed as industry.

The Nuclear Industry operates on a worldwide scale. It includes a wide range of participants, such as individuals, corporations, industry groups, United Nations organisations, other international bodies, and designated agencies accountable to national governments.

The key players in the Nuclear Industry are listed out as follows:

- Nuclear reactor builders and operators
- Organisations in the areas of Uranium mining, nuclear fuel, storage and waste
- Research and Development institutes
- Regulators
- National and international organisations
- Funding and insurance companies for nuclear projects

Nuclear Fuel

Nuclear fuel may be defined as the material which is essential for operating a nuclear reactor. In other words, it is the material which creates nuclear fission or a nuclear reaction that releases huge amount of heat. If this reaction is created inside a reactor, the generated heat is converted into electricity and in case of nuclear bomb it creates massive destruction and multi fold consequences. At present Uranium (U) and Plutonium (Pu) are the nuclear fuel known to mankind.

Nuclear Fuel Cycle

The nuclear fuel cycle, also known as the nuclear fuel chain, refers to the sequence of stages that nuclear fuel undergoes. This cycle includes front-end steps, where the fuel is prepared; service period steps, where the fuel is utilised in the reactor; and back-end steps, which involve safely handling, containing, reprocessing, or disposing of the spent fuel. When people think of nuclear power, they mostly associate it with nuclear reactors, but these reactors are only one part of the entire process, which includes significant activities before and after their operation. The cycle begins with uranium mining, which can be done through underground mines, open-pit mines, or in-situ leaching. The extracted uranium ore is then processed into a stable and concentrated form known as yellowcake, which is transported to a processing facility. There, yellowcake is converted into uranium hexafluoride and then enriched using various methods. This enriched uranium, now containing more than the natural 0.7% of U-235, is fabricated into fuel rods with specific composition and geometry suited to the intended reactor. These fuel rods remain in the reactor for around three operational cycles, during which about 3% of the uranium undergoes fission. After this, the rods are transferred to a spent fuel pool, allowing the short-lived radioactive isotopes created during fission to decay. Once the rods have cooled sufficiently both in terms of heat and radioactivity, they are either disposed of or reprocessed. If the spent fuel is not reprocessed, the system is called an open cycle or once-through fuel cycle. If the spent fuel undergoes reprocessing, it is referred to as a closed fuel cycle. The once-through fuel cycle process is described below. [5]

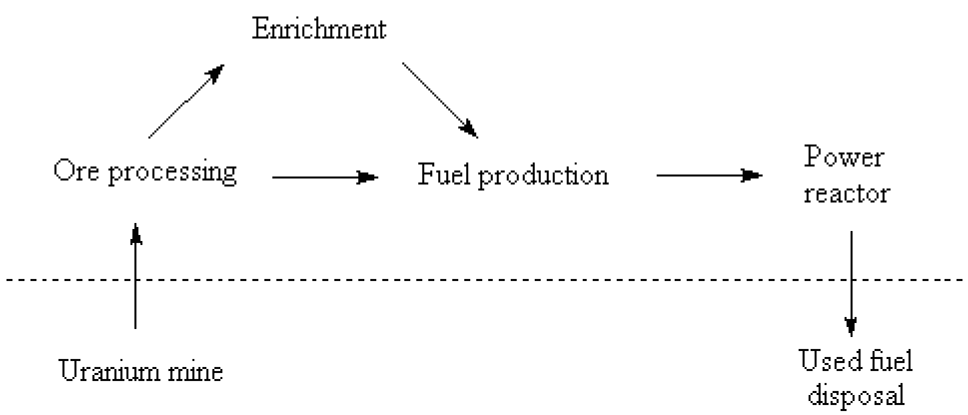

Figure 3.1 : Once Through Nuclear Fuel Cycle [5]
(Source: Nuclear Fuel cycle, Wikipedia)

A once through fuel cycle is not a cycle per se, fuel is used once and then sent to storage without further processing. Countries such as U.S.A, Sweden, South Africa, Canada, Finland and Spain follow this method.

A fuel cycle that utilizes plutonium as fuel is described below:

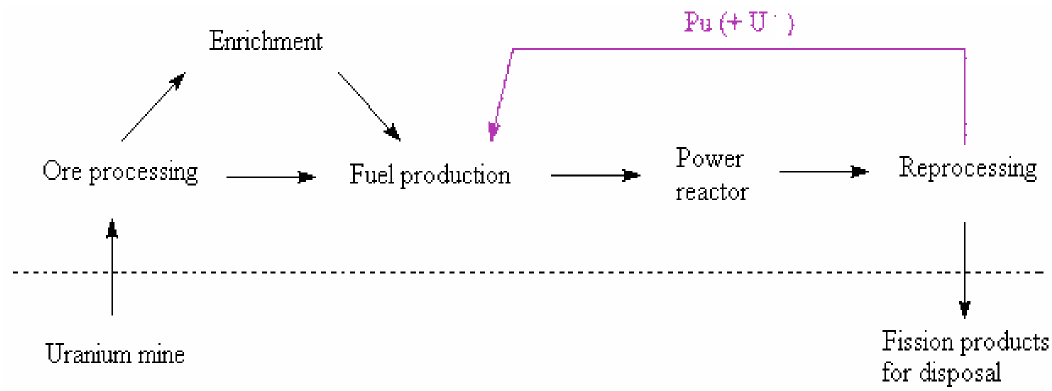

Figure 3.2 - Closed Fuel Cycle [5]
(Source: Nuclear Fuel cycle, Wikipedia)

Several countries are using the reprocessing services offered by British Nuclear Fuels Limited (BNFL) and former COGEMA (Compagnie générale des matières nucléaires) Now Orano. Here, the fission products, minor actinides, activation products and reprocessed Uranium are separated from the reactor grade Plutonium, which can then be fabricated into Mixed Oxide Fuel (MOX fuel). The proportion of the non-fissile even mass isotopes of Plutonium rises with each pass through the cycle, there are currently no plans to reuse Plutonium from used MOX fuel for a third pass in the thermal reactor. However, if fast reactors becomes available, they may be able to use it as a fuel.

Thorium Cycle

In the Thorium cycle, $Thorium_{232}$ absorbs a neutron in either a fast or thermal reactor. The $Thorium_{233}$ beta decays to $protactinium_{233}$ and then to $Uranium_{233}$ which in turn is used as fuel. Hence, like $Uranium_{238}$, $Thorium_{232}$ is a fertile material.

Thorium has the potential to be a better fuel source than Uranium. Thorium is at least four to five times more plentiful in nature compared to all Uranium isotopes combined. It is also more evenly distributed across the globe, with many countries having large reserves. Preparing Thorium fuel does not require the complex and costly enrichment process that Uranium needs. The Thorium fuel cycle mainly produces Uranium233 contaminated with Uranium232, making it more difficult to use for nuclear weapons.. However, there are challenges related to production, environmental impact, social acceptance, regulatory requirements, and technology that affect Thorium supply.

Current Industrial Activity

At present, the only isotopes used as nuclear fuel are Uranium235 (U235), Uranium238 (U238) and Plutonium239 (Pu239), although the proposed Thorium fuel cycle has advantages. Few reactors with minor modifications can use Thorium. Though more Thorium is available in earth, there has been minimal exploration for Thorium deposits, resulting in small confirmed reserves.

Reactors that use heavy water or graphite as moderators can operate with natural Uranium. However, the vast majority of reactors worldwide need enriched Uranium, where the proportion of U235 relative to U238 is increased. In civilian nuclear reactors, enrichment levels reach up to 5% U235 and 95% U238, whereas in naval reactors, enrichment can be as high as 93% U235.

Major Nuclear Power Countries in the World:

Table 3.1: Major Nuclear Power Countries in the World [6]
(Source: Statista.com)

Country	Reactors (No)	Fuel Cycle	Uranium Source	Reprocess ing	Waste Management	Key Points
U.S.A	94	Open	Domestic	Stopped since 1977	Stored at deep geological repository	Largest producer of nuclear power
China	58	Closed	Domestic + Imported	Domestic	Stored at waste storage sites	Aggressiv e expansion in nuclear power
France	57	Closed	Imported	Domestic	Stored at repositories	Produces 75% electricity from nuclear
Russia	36	Closed	Domestic + Imported	Domestic	Low & intermediate: deep well injection	Inherited facilities from USSR
Japan	33	Closed	Imported	Domestic	Interim storage at plants; final repository plans under discussion	Post-Fukushim a restart ongoing
India	23	Closed	Mostly Domestic + imported under agreements	Domestic	Interim storage at sites; plans for deep geological repository	Pursuing three-stage program

It can be said that U.S.A is leading player in nuclear power programme. It is followed by China and then France and Russia. These countries represent the leader board for Nuclear Power in the world.

Other Countries that Use Nuclear Power

Many countries around the world either generate electricity using nuclear power or are involved in some part of the nuclear fuel cycle. According to the "Country Nuclear Fuel Profile" report by the International Atomic Research Agency (IARA), around 38 countries have such profiles. Australia stands out as it is a major supplier of uranium but does not operate any nuclear power plants. South Korea (26), Canada (7), Ukraine (15), UK (9) are the other major countries in the world using Nuclear Power. Countries like Bangladesh currently have nuclear reactors under construction. Additionally, some nations not only use nuclear technology domestically but also export reactors and related services (like Russia, USA, France) while countries such as China aim to expand into large-scale nuclear exports.

India

India has one of the oldest nuclear programmes in the world. The country formally launched its nuclear efforts less than a decade after the discovery of nuclear fission and only six years after the Manhattan Project began. Notably, India started its programme seven years before China began its own in 1955.

A unique aspect of India's nuclear development is that it originated as a civilian initiative. Unlike other nuclear powers that initially focused on producing fissile material for weapons in military facilities and later shifted to electricity generation, India pursued both objectives together. For example, China only began constructing nuclear power plants in the 1980s. In contrast, India adopted a dual-use approach, establishing civilian nuclear infrastructure that could also support military purposes, such as producing weapon-grade fuel.

India's nuclear programme is built on strong foundations. It has consistently advanced its capabilities with a focus on self-reliance in nuclear science and technology. This comprehensive development includes exploration, mining, extraction, purification, and processing of nuclear materials; fuel element production; power reactor design and construction; heavy water production; health and safety systems; instrumentation; isotope separation; and all supporting disciplines in physics, chemistry, biology, engineering, and electronics.

History

India's nuclear journey began even before independence. It is perhaps the only nation where a scientist initiated the foundation of its nuclear industry. Moreover, India never aimed to become a nuclear weapons state. The Indian nuclear programme was conceptualised by Dr. Homi Jehangir Bhabha.The origins of India's atomic energy initiative date back to the early 1940s, even before the country gained freedom from British rule. In 1945, Dr. Bhabha set up the Tata Institute of Fundamental Research (TIFR) with the support of the Tata Trust, marking the first milestone in India's nuclear programme. Shortly after independence, the Atomic Energy Commission of India (AEC) was formed, with Dr. Bhabha as its first chairman. During these formative years, the close intellectual partnership between Dr. Bhabha and Prime Minister Jawaharlal Nehru laid the groundwork for India's later self-reliance in various scientific domains, including nuclear energy. [7]

Plutonium Route

There are two approaches towards nuclear power production. Option A is to obtain Plutonium by processing Uranium. Option B enriches natural Uranium (U_{235}) to highly enriched Uranium (HEU) by elaborate isotope-enrichment process, without use of reactors and chemical reaction. India opted for option A of Plutonium route.

Thorium fuel cycle developed by Dr. Bhabha

India possesses only a small amount of Uranium reserves but has significant Thorium resources. To address this, Dr. Homi Bhabha devised a unique three-stage nuclear strategy that utilizes Thorium while managing the shortage of Uranium.

In the **first stage**, India uses Pressurised Heavy Water Reactors (PHWRs) that run on natural Uranium. However, due to the limited availability of Uranium, the number of such reactors that can be built is restricted. Additionally, light water reactors are planned alongside PHWRs, mainly for electricity production. During this stage, Plutonium is produced as a by-product, which is extracted from Uranium-238.

The **second stage** involves fast breeder reactors that use Plutonium as fuel. These reactors have a surrounding blanket containing Uranium and Thorium, enabling them to produce more Plutonium (preferably high-fissile Pu) along with Uranium-233. Because these reactors generate more Plutonium than they consume, they are known as breeder reactors, effectively extending the utilisation of Uranium resources.

In the **third stage**, Advanced Heavy Water Reactors (AHWRs) will use a mix of Thorium and Plutonium as fuel. This process produces Uranium-233, which can then be used as a self-sustaining fissile material to fuel a series of AHWRs. Another potential option for stage three is the deployment of Molten Salt Breeder Reactors (MSBRs), which are emerging as viable alternatives for large-scale use.

The diagram below illustrates Dr. Bhabha's three-stage nuclear development strategy.

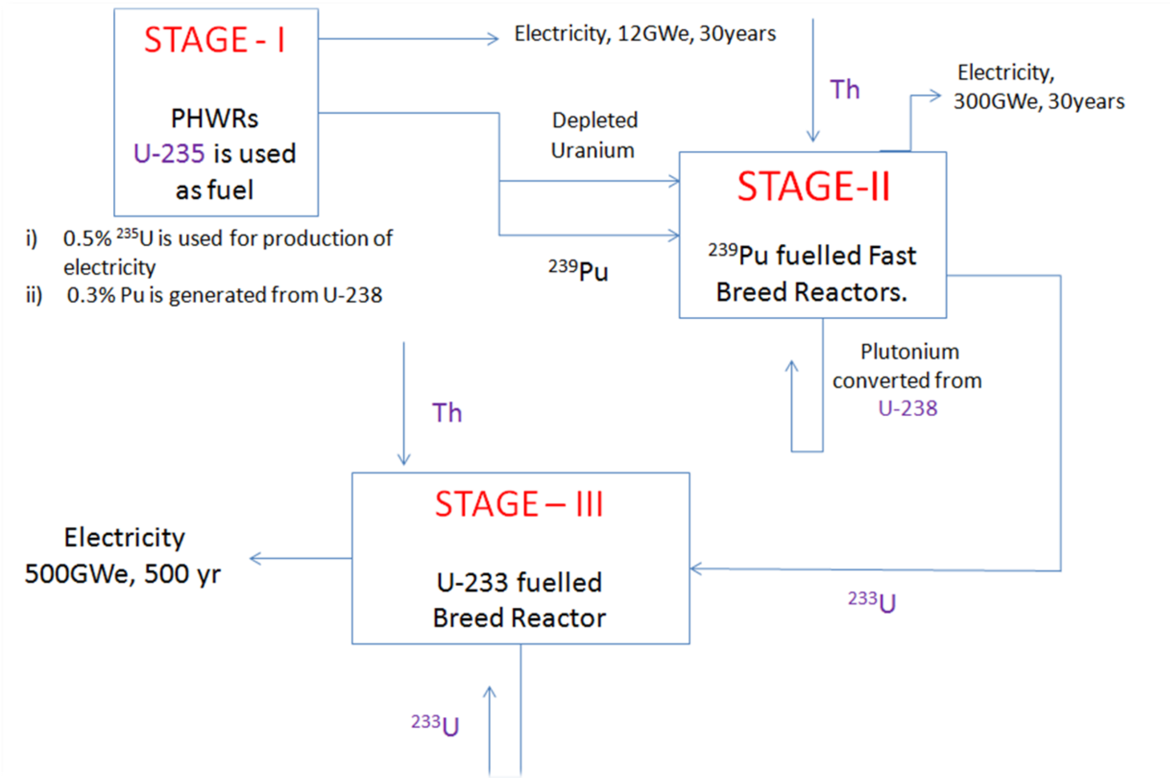

Figure 3.3 : Three Stage Strategy by Dr. Bhabha [8]
(Source: conceptualphysicstoday.com)

Dr. Bhabha designed the entire programme to bring in self-reliance and self-sufficiency. As a next step, Dr. Bhabha focused on setting up research facilities. The logic of it may not appeal to all; some critics may even describe it as reinventing the wheel. The truth is the real situation does not admit of simplistic solutions. Nuclear technology is so much entangled with international monopolies and vested interests that the know-how and the crucial equipment do not become available when it is most urgently needed.

For faster nuclear power capacity addition, in parallel to the indigenous three-stage program, additionalities based on imports have been introduced. Two VVER (Voda-Vodyanoi Energetichesky Reaktor) of 1000 MW each are constructed at Kudankulam in technical cooperation with the Russia. As capacity addition through the indigenous route is guided by the fuel cycle linkages of the sequential three-stage program, faster capacity addition in the near term to meet the electricity needs of the country will be possible through these additionalities.

India had natural resources required for nuclear industry i.e. both Uranium and Thorium along with this the programme was also found to be feasible. Hence, Dr. Bhabha developed a three stage programme specific to India based on its limited Uranium reserves and abundance Thorium reserves. To implement the plan, Dr. Bhabha initiated negotiations with other countries and entered into nuclear cooperation agreements through which the reactors were supplied to India.

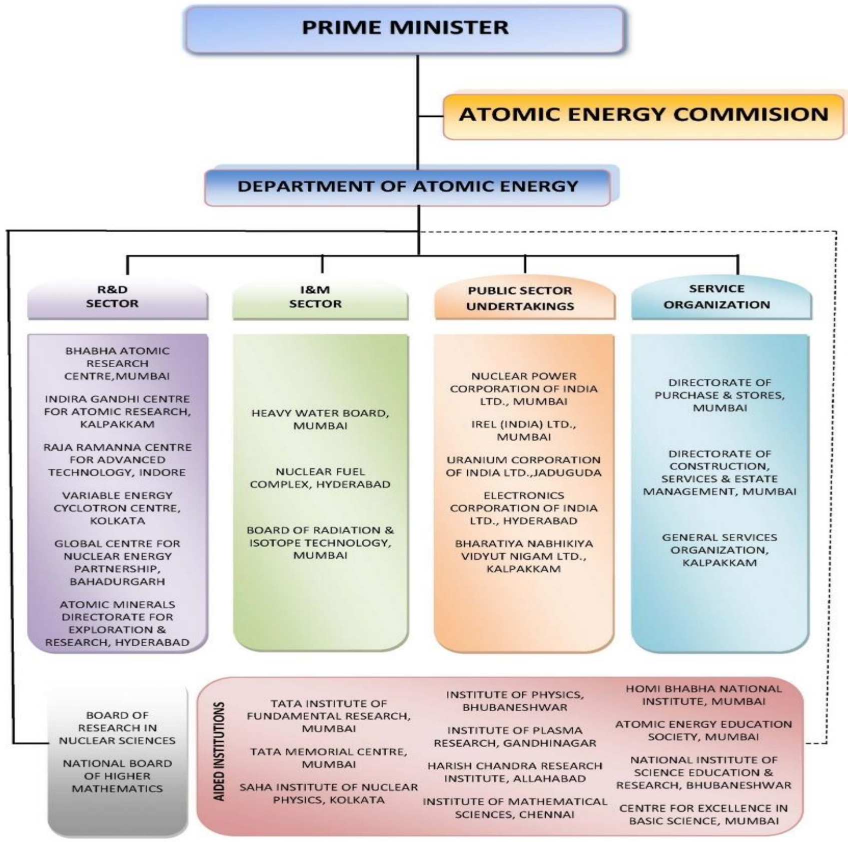

Figure 3.4: India's Nuclear Establishment Structure [9]
(Source: dae.gov.in)

Structure

Atomic Energy Act prohibits any private players in the nuclear field and all the activities are carried out only by Government of India. The private players act as contractors for Government undertakings and contribute in three major ways namely supplying components, civil construction and related activities and consulting related services. Dr. Bhabha not only initiated the nuclear industry of the nation but also developed its structure. He brought all activities related to atomic energy under direct supervision and control of Prime Minister of India who is also the Minister of Atomic Energy. Unusual for an Indian Government undertaking, Dr. Bhabha managed to obtain full functional and decision making autonomy for nuclear programme with nodal Department of Atomic Energy (DAE) having the freedom to set its own research and work agenda with oversight being exercised only by the Prime Minister in his concurrent capacity as Minister of Atomic Energy. Further DAE shared its location with

Atomic Energy Commission (AEC) in Mumbai was designed to keep it away from the central bureaucracy affecting the working of the nuclear establishment. The structure of nuclear establishment in India is given in Figure 3.4 : India's Nuclear Establishment Structure

Nuclear reactors in India are of two types namely research reactors and commercial reactors that are connected to grid and supply electricity. The research reactors are with research centres or more specifically with BARC and commercial reactors are owned and operated by NPCIL.

The details of commercial reactors under NPCIL are given in Table Below . NPCIL operates 23 reactors with total capacity of 8080 MWe.

Table 3.2: Operational Nuclear Power Plants of India [10]
(Source: npcil.nic.in)

Serial No.	**Power Station**	**Location**	**Reactor**	**Capacity (MW)**	**Start Date**
1	Tarapur Atomic Power Station-1	Tarapur,Near Mumbai	BWR	160	28-10-1969
2	Tarapur Atomic Power Station-2			160	
3	Tarapur Atomic Power Station-3		IPHWR-540	540	18-8-2006
4	Tarapur Atomic Power Station-4			540	15-9-2005
5	Rajasthan Atomic Power Station-2	Rawatbhata, Rajasthan	CANDU	200	1-4-1981
6	Rajasthan Atomic Power Station -3		IPHWR-220	220	1-6-2000

7	Rajasthan Atomic Power Station -4			220	23-12-2000
8	Rajasthan Atomic Power Station -5			220	4-2-2010
9	Rajasthan Atomic Power Station -6			220	31-3-2010
10	Madras Atomic Power Station -1	Kalpakkam, Tamil Nadu	IPHWR-220	220	27-1-1984
11	Madras Atomic Power Station -2			220	21-3-1986
12	Narora Atomic Power Station -1	Narora, Uttar Pradesh	IPHWR-220	220	1-1-1991
13	Narora Atomic Power Station -2			220	1-7-1992
14	Kakrapar Atomic Power Station -1	Kakrapar, Gujarat	IPHWR-220	220	6-5-1993
15	Kakrapar Atomic Power Station -2			220	1-9- 1995
16	Kakrapar Atomic Power Station -3		IPHWR-700	700	22-7-2020
17	Kakrapar Atomic Power Station -4			700	17-12-2023
18	Kaiga Generating Station -1	Kaiga, Karnataka	IPHWR-220	220	6-11-2000

19	Kaiga Generating Station -2			220	6-5-2000
20	Kaiga Generating Station -3			220	6-5- 2007
21	Kaiga Generating Station -4			220	27-11-2010
22	Kudankulam Nuclear Power Plant -1	Kudankulam, Tamil Nadu	VVER-1000	1000	22 October 2013
23	Kudankulam Nuclear Power Plant -2			1000	10 July 2016
	Total Capacity			**8080**	

Table 3.3: Under Construction Nuclear Power Plants of India [10]
(Source: npcil.nic.in)

Serial No.	Power Station	Location	Reactor	Capacity (MW)	Expected Year
1	Rajasthan Atomic Power Station -7	Rawatbhata, Rajasthan	IPHWR-700	700	2025
2	Rajasthan Atomic Power Station -8			700	
3	Gorakhpur Haryana Anu Vidyut Pariyojana -1	Gorakhpur, Haryana		700	2028

4	Gorakhpur Haryana Anu Vidyut Pariyojana -2			700	
5	Kaiga Generating Station -5	Kaiga, Karnataka		700	2026
6	Kaiga Generating Station -6			700	
7	Kudankulam Nuclear Power Plant -3	Kudankulam, Tamil Nadu	VVER-1000	1000	2025
8	Kudankulam Nuclear Power Plant -4			1000	
9	Kudankulam Nuclear Power Plant -5			1000	2027
10	Kudankulam Nuclear Power Plant -6			1000	
	Total Capacity			**8200**	

Table 3.4 : Proposed Nuclear Power Plants of India [10]
(Source: npcil.nic.in)

Power Station	**Reactor**	**Capacity (MW)**	**Status**
Jaitapur (Maharashtra)	EPR	9900 (6 × 1650 MW)	EDF submitted its techno-commercial proposal in 2020, but construction and progress have been delayed because of nuclear

			liability concerns.
GHAVP-3 and 4 (Gorakhpur, Haryana)	IPHWR-700	1400 (2 × 700 MW)	Under Package Award stage.
Mithi Virdi in Gujarat	LWR	6000 (6 × 1000 MW)	The project was relocated to Kovvada in Andhra Pradesh because of protests and delays in acquiring land.
Kovvada in Andhra Pradesh	LWR	7248 (6 × 1208 MW)	The project was enhanced from 6000 MW (6 units of 1000 MW each) to 7248 MW (6 units of 1208 MW each), with in-principle approval granted in December 2023.
Chutka Nuclear Power Plant in Madhya Pradesh	IPHWR-700	1400 (2 × 700 MW)	A Joint Venture agreement was signed between NPCIL and NTPC in May 2023 to build an indigenously developed nuclear reactor.
Bhimpur, Shivpuri in Madhya Pradesh		2800 (4 × 700 MW)	There have been no new developments or announcements regarding the nuclear power plant.
Mahi Banswara Rajasthan Atomic Power Project			In May 2023, NPCIL and NTPC signed a Joint Venture agreement to construct a nuclear reactor built with indigenous technology.
Haripur Nuclear Power Project, West Bengal	VVER-1000	6000 (6 ×1000 MW)	In-principle approval was granted in 2015, but the West Bengal state government refused to approve the project, resulting in its halt.

India's Fuel Cycle

- India has a flourishing and largely indigenous nuclear power programme. It aims to supply 25% of electricity from nuclear power by 2050.

- India was largely excluded from trade in nuclear plant or materials as the country is not a party to NPT.
- Due to trade bans and lack of indigenous Uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of Thorium.
- India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and Thorium fuel cycle.

India follows closed fuel cycle. India is one of the few countries that has developed expertise in all areas of the nuclear fuel cycle and allied fields covering mineral exploration, mining, heavy water production, fuel fabrication, fuel reprocessing and the management of nuclear waste.

Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of nuclear power plants.

The country is taking efforts in moving to second level in the three stage fuel cycle programme developed by Dr. Bhabha by developing the Fast Breader Reactor at Kalpakkam. Still the nuclear industry contributes close to 2% of nation's electricity. The projects are having issues in delayed implementation. The country had entered into 123 agreement with U.S.A and obtained Nuclear Suppliers Group (NSG) waiver in nuclear trade. This has brought in more opportunities to the nuclear industry as a whole.

Nuclear Autonomy

The word autonomy means independence or freedom, the condition of being autonomous; self - governance. Nuclear autonomy means having independence in the nuclear fuel cycle. Nuclear autonomy is seen as one of the most significant features and can serve multiple purposes: social and technological development, political power and commercial interests. Countries who pursue nuclear programmes desire to attain nuclear autonomy. If a country does not have nuclear autonomy or in other words if the country is dependent on outside support or assistance for its nuclear programme to that extent its strategic interests can be affected. India has a full-fledged nuclear cycle and the industry has been developed indigenously without much of external support. The country has considerable reserves of nuclear fuel namely Uranium and Thorium. However, the country does not have fuller and complete nuclear autonomy. This is mainly on account of two reasons namely availability of enriched Uranium and Reactors. The country still dependent on imported Uranium as a fuel for its reactors and the country is still importing nuclear reactors from other countries.

After joining the Nuclear Suppliers Group (NSG) in 2008, India signed civil nuclear cooperation agreements with several countries, including the USA, Russia, France, the UK, South Korea, the Czech Republic, Canada, Australia, Argentina, Kazakhstan, Mongolia, and Namibia. In November 2015, India signed an additional agreement with the UK covering a wide range of collaboration on energy and climate change, amounting to £3.2 billion ($4.9 billion) in programmes and initiatives aimed at enhancing energy security and access.

With extensive experience in operating Pressurised Heavy Water Reactors (PHWRs), India has progressed to the commercial demonstration stage of its Fast Breeder Reactor (FBR) programme, having set up its first 500 MWe prototype FBR at Kalpakkam. Moreover, India is emerging as a leader in developing reactor and fuel cycle technologies for Thorium utilisation. However, there remains a significant gap in terms of the "degree of nuclear industry" development, as India continues to rely on imported fuel and reactors. Since fuel largely depends on natural resources, there is limited scope for creating these resources. India's three-stage nuclear programme is structured to address this limitation of Uranium by leveraging its abundant Thorium reserves. Currently, India has entered in the second stage of this programme and still has a long way to go to fully meet its raw material needs. Similarly, in the area of reactor construction, the country must advance towards building reactors indigenously.

Indian Nuclear Liability Act

Operators of nuclear power plants are held responsible for any harm their plants cause, regardless of who is at fault. Nuclear accidents can result in massive damage because radiation severely affects living beings and the environment, with effects lasting for decades. To cover such risks, plant operators usually take out third-party liability insurance, and in many countries, this insurance is mandatory.

In India, the Civil Liability for Nuclear Damage Act (CLNDA) was enacted in 2010, which transferred full liability for any nuclear accident damages to NPCIL. The Act created a liability-free framework for foreign reactor suppliers to encourage their participation and investment in India's nuclear sector. However, suppliers have raised concerns over three specific clauses: Clause 6, which sets limits on liability; Clause 17, which allows for the right of recourse against suppliers; and Clause 46, which states that the Act applies in addition to other laws. [11]

Private Players in Indian Nuclear Industry

Currently, all nuclear power generation activities in India are managed by NPCIL, a Government of India enterprise. However, some private companies are involved as suppliers, offering products or services to government bodies, with both domestic and international players participating in this role. Major players include BHEL,L&T, Siemens, GE *(Now Arabelle Solutions)* , KSB etc.

Proposed Amendments to the Atomic Energy Act, 1962

In the Union Budget 2025, the Government of India announced plans for two major amendments to the Atomic Energy Act to promote private and foreign participation in the nuclear sector.

According to reports, the first amendment will relax provisions of the nuclear liability law by capping the liability of equipment suppliers in case of an accident. This cap would limit their financial responsibility to the original contract value and potentially restrict the duration for which liability would apply.

The second amendment aims to allow private companies to operate nuclear power plants within India. This change could also permit foreign companies to hold minority stakes in future nuclear power projects. Through these amendments, even foreign firms could enter nuclear power generation as operators, which is currently reserved only for state-owned entities like NPCIL and NTPC Ltd.

The Civil Liability for Nuclear Damage Act, 2010, was designed to ensure compensation for victims in the event of a nuclear accident by defining liabilities and compensation procedures. However, foreign companies such as GE-Hitachi, Westinghouse and EDF have considered this Act a barrier to investment in India's nuclear sector due to concerns over their potential future liabilities as suppliers. [12]

Since atomic energy has traditionally been a highly restricted sector in India, these two amendments are expected to open the doors for increased foreign investment and greater private participation.

Government Companies like NTPC and IOCL and Private Players like Reliance, Vedanta, Tata Power have shown interest in entering into Nuclear Power after Government's signal of key Amendments to Atomic Energy Act. [13] [14] There are few initiatives taken recently by Government of India which can improve the competitiveness of Nuclear Power Industry.

. Key Initiatives of Government of India are given as follows:

- Government of India sets a target of 100GW Nuclear Power by 2047 as part of Viksit Bharat 2047.
- Considering Amendments to Atomic Energy Act to bring Private Sector Participation.
- Develop Supporting Industries through technology transfer agreements with foreign players. [15]

- Allocation 20000 Crore for Research & Development on Small Modular Reactor with target of five indigenously designed Small Modular Reactor (SMR) by 2035.
- Government is working on streamlining the regulatory process to shorten the project timelines for Nuclear Power.

CHAPTER 4: RESEARCH METHODOLOGY

Nuclear power is witnessing a global resurgence due to rising energy demands and the need for reliable and clean energy sources. The Government of India is also optimistic about this sector and has set an ambitious target of achieving 100 GW of nuclear power capacity by 2047. Therefore, the researcher felt it was important to assess the competitiveness of India's nuclear power industry to identify key areas for improvement and growth.

This research is designed to explore and understand the nuclear power industry using a case study approach to derive strategic insights. Data for the study was collected through a review of online articles, books, journals, and interactions with various professionals in the nuclear power sector.

The analysis was conducted using Michael Porter's renowned strategic model, "Competitive Advantage of Nations", commonly known as the "Diamond Model". Michael Porter's Diamond Model was chosen as it provides a comprehensive and proven framework to analyse nation's industry competitiveness by examining key factors such as factor conditions, demand conditions, supporting industries, and rivalry. Its holistic approach aligns with the study's objective to identify strengths, weaknesses, and growth opportunities in India's nuclear power industry, offering practical insights for both managers and policymakers.

Competitive Advantage of Nations

Competitive Advantage of Nations is the famous strategical model developed by Michael E Porter of United States of America (USA). This study was first published as an article in Harvard Business Review (HBR) and latter published as a book. In this model, the author explains how the countries can be competitive in the international industry. This has brought in a considerable amount of change in the mind set of Governments/political leaders in the way they are approaching towards economic development and international competition.

National Competitiveness – Meaning and Concepts

National competitiveness has turned into a major focus for governments and industries worldwide. Moreover, there isn't even a universally agreed definition of what "competitiveness" means when referring to a country. Although the idea of a competitive business is straightforward, the concept of a competitive nation remains unclear.

To begin with, competitiveness can be described as a macroeconomic concept influenced by factors like exchange rates, interest rates, and government budget deficits. However, countries such as Japan, Italy, and South Korea have all seen significant improvements in their living standards despite having budget deficits; Germany and Switzerland have achieved this despite their strengthening currencies; and Italy and Korea have raised their living standards even with high interest rates.

Secondly, it is often believed that competitiveness depends on cheap and plentiful labour. However, countries like Germany, Switzerland, and Sweden have thrived despite having high wages and labour shortages. Porter questions this notion, pointing out that competitive nations actually aim for better wages for their workforce.

Thirdly, many think that having abundant natural resources leads to competitiveness. Yet, Germany, Japan, Switzerland, Italy, and South Korea have become highly successful despite their limited natural resources, challenging this assumption.

Fourthly, another popular argument is that Government policies such as targeting, protectionism, import restrictions, and subsidies drive competitiveness. This is often cited in the rise of Japanese and South Korean industries like automobiles, steel, shipbuilding, and semiconductors. But a closer examination shows mixed results. For example, Italy’s Government interventions have largely been ineffective, yet Italy has achieved significant export growth, second only to Japan. In Germany, there is minimal direct Government involvement in export industries. Even in Japan and South Korea, Government intervention has been limited in critical sectors like copiers, robotics, advanced materials, and facsimile machines, with famous examples like steel and shipbuilding now outdated.

Finally, some argue that competitiveness depends on management practices, including labour relations. However, management approaches differ across industries based on product types, life cycles, and investment needs. For instance, family-run management suits Italian footwear, textiles, and jewellery industries, but is not ideal for German chemical or automobile firms, Swiss pharmaceutical companies, or American aerospace manufacturers. Likewise, labour relations cannot be generalised. Despite beliefs that strong unions reduce competitiveness, countries like Germany and Sweden have powerful unions and still host globally leading firms.

In summary, none of these factors alone fully explain a nation’s industrial competitiveness. While each holds partial truth, a more comprehensive and multifaceted set of forces influences national competitive positions.

Does a “competitive” nation simply mean a country whose exchange rate makes its products cheaper in global markets? Both Germany and Japan have achieved significant improvements in their living standards while having strong currencies and increasing prices for long periods. Does being "competitive" mean having a large trade surplus? Switzerland maintains roughly balanced trade, and Italy often runs a trade deficit, yet both countries have seen their national incomes grow substantially. Does competitiveness imply low labour costs? Countries like India and Mexico have low wages and labour expenses, but neither is considered an ideal industrial model. [4]

Competitiveness and Productivity

The only truly relevant measure of a nation's competitiveness is its productivity. The main objective of any country is to ensure a high and continuously improving standard of living for its people. Achieving this depends on how efficiently the nation utilises its labour and capital resources.

A country's standard of living relies on its businesses' ability to attain high productivity levels and to enhance productivity continuously. Consistent growth in productivity demands that an economy constantly advances itself. Companies within a nation need to persistently enhance productivity in their current sectors by improving product quality, incorporating appealing features, upgrading product technology, or increasing production efficiency. They also need to build the essential skills to compete in increasingly advanced industry segments, which usually have high productivity. Ultimately, they must acquire the ability to compete in completely new and complex industries. [4]

Global Trade and Productivity

Global trade and overseas investment can both enhance and endanger a country's productivity. They boost national productivity by enabling a country to focus on those industries and industry segments where its firms are more efficient, and to import products where its firms are less efficient. No country can maintain competitiveness in every sector. The key is to allocate the nation's limited human and other resources to their most efficient uses. Even nations with the highest living standards have numerous sectors where domestic firms lack competitiveness.

However, global trade and foreign investment can also pose a threat to productivity growth. They subject a country's industries to international productivity benchmarks. An industry will fail if its productivity isn't sufficiently greater than that of foreign competitors to counterbalance any local wage advantages. If a country loses competitiveness in various high-productivity and high-wage sectors, its standard of living comes under threat.

Defining national competitiveness merely as having a trade surplus or balanced trade is inaccurate. Export growth due to low wages and a devalued currency, while simultaneously importing advanced products that domestic companies cannot produce efficiently, might balance or surplus trade but actually reduces the nation's living standards.

Moreover, competitiveness is not simply about employment. The nature of jobs matters; economic prosperity depends on the quality of jobs rather than just the ability to employ people at low wages. Therefore, attempting to define "competitiveness" at the national level addresses the wrong issue. What truly needs to be understood are the factors that drive productivity and the pace of productivity growth. To get the answers, we need to look at individual industries and their specific segments rather than the entire economy. National productivity improves through countless battles for competitive advantage within these particular segments and industries, where new products and processes are developed and enhanced.

When examining any country's economy closely, one can see that different industries within the nation show varying levels of competitive success. Often, international competitiveness is concentrated in specific industry segments. For example, Germany's car exports are largely focused on high-performance vehicles, whereas South Korea mainly exports compact and subcompact cars. In many sectors and their segments, only a few countries have firms with genuine international competitive advantages.

Therefore, the main question becomes: what is the key trait of a nation that enables its firms to develop and maintain competitive advantages in certain fields? This leads to the concept of national competitive advantage. The focus here is on understanding the factors that drive international success in technology- and skill-intensive sectors, as these are critical for achieving high and growing productivity levels.

Traditional economic theory attributes a nation's success in specific industries to its factors of production, such as land, labour, and natural resources. Countries are thought to gain comparative advantage in industries that utilise their abundant factors. However, this classical view has been challenged in today's advanced industries and economies, where global competition and technological capabilities play a far greater role.. [4]

Nature of Theories and Reality

A new theory needs to acknowledge that in today's international competition, companies use global strategies that include not just trade but also foreign investments. This theory should clarify why certain countries provide an advantageous home base for firms competing globally. The home base is the country where a company's critical competitive strengths are developed and maintained. It is the location where strategy is formulated, where core product and process technologies are created and updated, and where the most productive jobs and advanced skills are found. Having a home base in a country positively influences other related domestic industries and brings additional economic benefits to the nation. Although company ownership is often centred in the home country, the nationality of shareholders is of lesser importance.

This new theory needs to progress beyond the traditional concept of comparative advantage to encompass the idea of national competitive advantage. It should embrace a comprehensive view of competition that includes market segmentation, product differentiation, technological disparities, and economies of scale. The theory must also explain why companies from some countries outperform others in building advantages based on quality, features, and innovation in new products. According to Porter, such a theory must start with the understanding that competition is dynamic and continuously evolving, and it must explain the following aspects.

- Reasons for few companies more innovative than others
- Reasons for how some nations provide an environment that enables companies to improve and innovate faster than foreign rivals.

Competitive Advantage of Countries

Below is an excerpt from Porter's Harvard Business Review article on "Competitive Advantage of Nations":

A country's prosperity is built rather than inherited. Unlike what classical economics claims, it does not stem from natural resources, workforce size, interest rates, or currency value. The real competitiveness of a nation lies in its industries' ability to innovate and improve.

Companies outperform top global competitors due to constant pressure and challenges. They gain from having strong local competitors, assertive domestic suppliers, and demanding local customers. Even in today's world of global competition, the role of the nation has become more crucial. As competition increasingly relies on creating and absorbing knowledge, the importance of national context has grown.

Competitive advantage is developed and maintained through a deeply localised process. National values, culture, economic structure, institutions, and history all shape a country's success. Every country shows unique competitiveness patterns; no nation is competitive in all or even most industries. In the end, a nation excels in specific industries because its domestic environment is dynamic, progressive, and challenging.

In this context, a fresh outlook with new tools are required; an effort to competitiveness that emerges from analyzing industries that have succeeded internationally, without being influenced by traditional beliefs or current academic trends. It is essential to understand, in simple terms, what actually works and why it works, and then implement those insights. When examining how companies succeed in global markets, it is evident that firms with international leadership use strategies that vary greatly from one another. However, although each successful company follows its own unique strategy, the core way they operate, their nature, and their overall growth pattern are fundamentally similar. [4]

Needs

Firms gain competitive advantage through innovative actions. Certain innovations provide an edge by identifying completely new market opportunities or targeting market segments overlooked by competitors. However, some innovations that address specific issues or conditions unique to the domestic market can actually hinder success in international competition.

Information has a significant part in driving innovation and continuous improvement. A company that manages to introduce a new or improved way of competing does so with relentless determination, often pushing forward despite severe criticism and major challenges. In reality, for innovation to succeed, it usually needs pressure, urgency or even difficult circumstances. The fear of losing something often serves as a stronger motivator than the hope of gaining something.

In the end, any company that ceases to improve or innovate will inevitably be surpassed by its competitors. The only way to maintain a competitive edge in the long run is to constantly enhance and upgrade it.

Determinants of National Competitive Advantage

The four major characteristics of a nation, which both individually and collectively form the ‘Diamond’ of national advantage, create the competitive environment in which its industries function. These characteristics are:
A. Factor Conditions
B. Demand Conditions
C. Related and Supporting Industries
D. Firm Strategy, Structure and Rivalry

These factors shape the national setting where firms emerge and develop their competitive abilities. Each element of the diamond, as well as the diamond as a whole, serves as a crucial component for attaining global competitiveness. The following diagram illustrates the diamond model, with a short explanation of each of its four determinants provided below it.

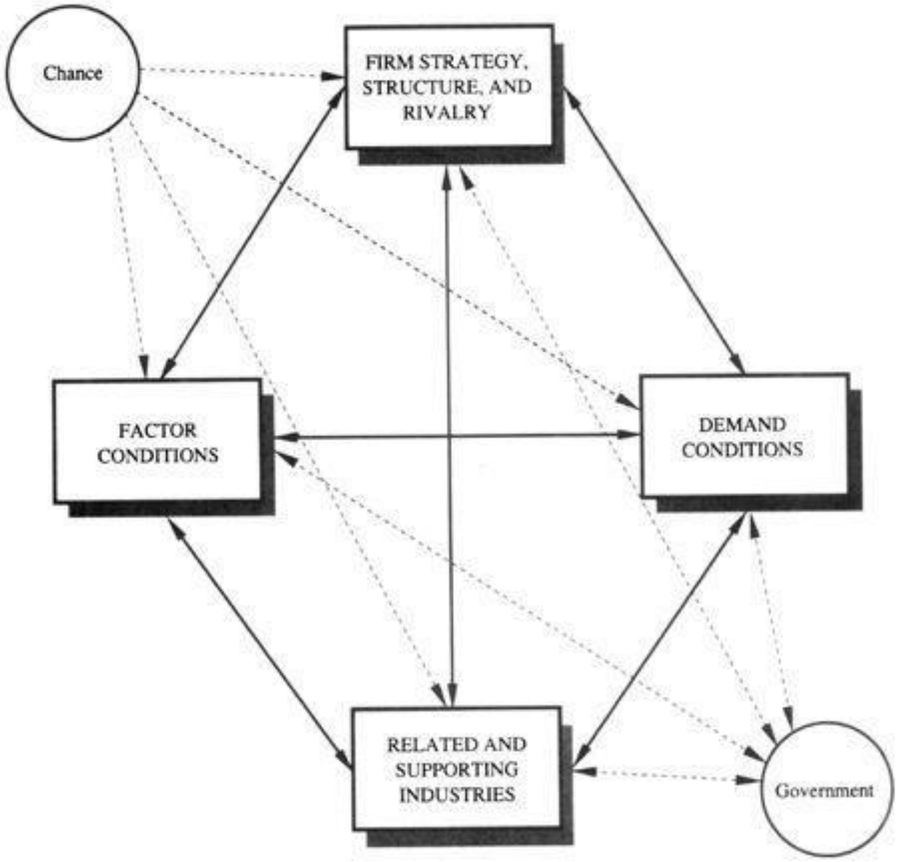

Figure 4.1 : Determinants of National Competitive Advantage [4]
(Source: M. E. Porter, Competitive Advantage of Nations)

Factor Conditions

Traditional economic theory suggests that factors of production such as labour, land, natural resources, capital, and infrastructure, determine trade patterns. According to this view, a country will export products that make the greatest use of the resources it has in abundance. This idea, originating from economists like Adam Smith and David Ricardo and forming the basis of classical economics, is at best incomplete and at worst inaccurate.

In advanced economies, particularly in sophisticated industries, the most crucial factors of production are not inherited but created, such as skilled talent or a strong scientific foundation. Furthermore, the quantity of factors a nation possesses at a given time is less important than how effectively and rapidly it can develop, enhance, and utilise them within specific industries. The most valuable production factors are those requiring continuous and significant investment and that are highly specialised.

Basic resources, like a general labour pool or local raw materials, do not provide an edge in knowledge-intensive sectors. Companies can easily access such inputs globally or replace them with technological solutions. Contrary to popular belief, merely having a general workforce with high school or even college education does not create a competitive advantage in today’s international markets.

For a factor to contribute to competitive advantage, it must be highly specialised to the specific needs of an industry such as an optics-focused research institute or a pool of venture capital targeted at funding software firms. These specialised resources are scarce, difficult for foreign competitors to replicate, and require continuous investment to develop. Countries excel in industries where they are particularly strong in creating such factors. Competitive advantage stems from having world-class institutions that first develop specialised resources and then consistently work to upgrade them.

When there is a plentiful availability of inexpensive raw materials or an excess of labour, companies tend to rely on these benefits and often use them inefficiently. However, when firms encounter specific disadvantages, such as expensive land, a shortage of labour, or a lack of local raw materials, they are compelled to innovate and improve to remain competitive. Embedded within the frequently cited Japanese phrase, “We are an island nation with no natural resources,” is the recognition that these shortcomings have actually driven Japan’s innovative competitiveness. For instance, just-in-time production methods helped save on extremely costly space.

Italian steel manufacturers in the Brescia region faced similar disadvantages: steep capital costs, high energy prices, and no local access to raw materials. Situated in Northern Lombardy, these privately owned firms bore huge logistical expenses due to their distance from southern ports and inefficiencies in the state-run Italian transport network. As a solution, they pioneered technologically advanced mini-mills that required relatively low capital investment, consumed less energy, used scrap metal as input, operated efficiently at small scales, and allowed producers to set up near scrap sources and end users. In essence, they turned their factor disadvantages into competitive strengths.

However, disadvantages become advantages only under certain conditions. Firstly, they need to send companies clear signals about challenges that will eventually spread globally, giving them the chance to innovate before foreign competitors. Switzerland illustrates this well; as the first country to face labour shortages after World War II, Swiss firms responded by enhancing labour productivity and moving into higher-value, more sustainable market segments. Meanwhile, companies in other countries, where labour was still abundant, focused on different issues, which led to slower progress in upgrading.

The second requirement for turning disadvantages into advantages is having supportive conditions elsewhere within the diamond framework, a principle relevant to almost all determinants. For companies to innovate, they need skilled personnel and domestic demand conditions that provide the right market signals. Additionally, the presence of strong local competitors is crucial as it creates pressure to innovate. Another important factor is having corporate goals that encourage long-term commitment to the industry. Without such dedication and competitive pressure, firms might look for easy solutions to overcome disadvantages instead of using them as motivation for innovation. For instance, American consumer electronics firms, facing high labour costs, opted to keep their products and production methods largely unchanged and instead shifted labour-intensive work to countries like Taiwan and others in Asia to reduce costs. Rather than upgrading their competitive strengths, they simply aimed for labour cost equality. In contrast, Japanese companies, dealing with strong local competition and a saturated domestic market, responded by eliminating labour costs through automation, thereby strengthening their competitive edge.This resulted in reduced assembly expenses, products with fewer parts, and enhanced quality and reliability. Before long, Japanese firms began setting up assembly plants within the United States, in locations that American companies had previously abandoned. [4]

Demand Conditions

The globalization of competition might appear to reduce the significance of domestic demand. However, in reality, this is not true. The structure and nature of the home market often have an outsized influence on how firms understand, interpret, and react to consumer needs. Countries develop competitive advantages in industries where domestic demand offers their firms an earlier or clearer understanding of emerging customer preferences and where exacting buyers push firms to innovate rapidly and achieve more advanced competitive strengths than their international rivals.

The size of domestic demand is far less crucial than its nature. Home demand conditions foster competitive advantage when a particular industry segment is larger or more prominent in the local market compared to international markets. Companies tend to prioritise the biggest market segments within their own country while giving less attention to smaller or less attractive segments. For instance, hydraulic excavators are the most common type of construction equipment in Japan’s domestic market, while they form a much smaller portion of the market in other developed countries. This is one of the few segments where Japanese firms remain strong global competitors and where Caterpillar does not dominate the global market.

Even more critical than the market segment mix is the sophistication of domestic buyers**.** Firms gain competitive advantage if their home buyers are the world’s most advanced and demanding for that product or service. Such sophisticated consumers provide insights into advanced market needs, push firms to uphold high standards, and drive them to innovate and upgrade into more advanced segments.

Similar to factor conditions, demand conditions benefit companies by challenging them to address tough market requirements. Particularly strict demands often arise from local cultural values and living conditions. For example, Japanese consumers, living in compact and crowded homes, face hot, humid summers along with expensive electricity. In response, Japanese firms have developed compact, quiet air conditioners equipped with energy-efficient rotary compressors. Time and again, the strict requirements of the Japanese market have compelled firms to innovate, creating products that are “kei haku tan sho” – light, thin, short, and small – which are widely accepted internationally.

More broadly, companies within a country can predict global trends when the nation’s cultural values are gaining international influence – meaning the country is exporting its preferences and lifestyles along with its products. For instance, the global success of American companies in sectors like fast food and credit cards demonstrates not just the American preference for convenience but also how these preferences have been adopted worldwide. Countries spread their values and tastes via media, educating foreign nationals, political power, and through their citizens and businesses operating abroad. [4]

Related & Supporting Industries

The third major factor contributing to national advantage is the existence of internationally competitive related and supporting industries within a country. Having strong domestic suppliers gives downstream industries multiple benefits. Firstly, these suppliers provide inputs that are cost-effective, efficient, timely, and often with priority access. For example, Italian jewellery manufacturers dominate globally partly because Italian firms also produce two-thirds of the world’s jewellery making and precious metal recycling equipment. However, beyond merely obtaining parts and machinery, the true strength of local related and supporting industries lies in fostering innovation and continuous improvement through close collaboration. When suppliers and end users are located near each other, they benefit from efficient communication, a steady exchange of information, and ongoing sharing of ideas and innovations. Companies can influence suppliers’ technical developments and act as testing grounds for their research, thereby speeding up innovation.

Companies gain the most when their suppliers are themselves internationally competitive. Relying on “captive” suppliers who depend entirely on domestic firms and are restricted from serving foreign markets ultimately weakens competitiveness. That said, a country does not need to be globally competitive in every supplier industry for its firms to maintain an advantage. Firms can easily procure materials, parts, or technology from abroad without significantly affecting their innovation or product performance. This also applies to general-purpose technologies like electronics or software, where the industry is only a small user segment.

Competitiveness in related domestic industries offers similar advantages, such as rapid information exchange and technical collaboration that accelerates innovation and upgrading. Additionally, related industries foster the development of new skills and provide potential new entrants who bring innovative competitive approaches. For instance, Switzerland's pharmaceutical leadership evolved from its earlier success in the dye industry, while Japan's dominance in electronic keyboards stems from its achievements in acoustic instruments combined with its strong consumer electronics sector. [4]

Firm Strategy, Structure and Rivalry

Countries also vary significantly in the goals pursued by their companies and individuals. These corporate goals are influenced by the nature of national capital markets and managerial compensation structures. For instance, in Germany and Switzerland, where banks hold a large portion of company shares, stocks are generally kept for long-term gains and are infrequently traded. As a result, firms in these countries excel in established industries that require continuous investment in research and development and new facilities, even if the financial returns are only moderate.In contrast, the United States represents the other extreme, with abundant risk capital, frequent trading of public company shares, and investors who focus heavily on quarterly and annual increases in share prices. Management pay in the U.S. largely depends on annual bonuses linked to individual performance. Consequently, the U.S. thrives in newer sectors such as software and biotechnology or in industries where equity investment in start-ups drives strong domestic competition, like specialty electronics and services. However, in more mature industries, intense pressure to deliver short-term results often leads to underinvestment.

Countries often excel in fields that their people respect or rely upon, or in areas that produce national heroes. For example, Switzerland is strong in banking and pharmaceuticals, while Israel focuses on agriculture and defence. Sometimes it is difficult to tell whether prestige leads to success or success brings prestige, as international achievements often boost an industry's reputation and reinforce its strengths. Having strong local competitors is another major factor that drives and maintains competitive advantage. This is evident in small nations like Switzerland, where competition among pharmaceutical giants such as Hoffmann-La Roche, Ciba-Geigy, and Sandoz secures their global leadership. The same applies to the U.S. in its computer and software sectors. In Japan, this intense competition is especially visible, with 112 companies in machine tools, 34 in semiconductors, 25 in audio equipment, and 15 in cameras, highlighting how multiple firms compete in industries where Japan leads globally. Among all the elements of the diamond model, domestic rivalry is perhaps the most crucial due to its strong positive impact on the other determinants.

Traditional thinking suggests that domestic competition is inefficient because it causes duplicated efforts and stops companies from achieving economies of scale. However, domestic competitors engage in intense battles; they vie not only for market share but also for top talent, technological superiority, and, importantly, for reputation and prestige. When one local competitor succeeds, it demonstrates to others that progress is achievable, often drawing additional competitors into the industry. Firms often blame the success of foreign competitors on “unfair” advantages, but with domestic competitors, such excuses do not hold. Geographic concentration amplifies the impact of domestic competition. This pattern is common worldwide. For example, Italian jewellery manufacturers cluster around Arezzo and Valenza Po, while cutlery producers in West Germany are concentrated in Solingen. The more geographically concentrated the competitors are, the fiercer the rivalry becomes – and such intense competition is highly beneficial. Another advantage of domestic rivalry is the relentless pressure it puts on firms to continually upgrade their competitive strengths.

Having local competitors immediately eliminates advantages that arise merely from being based in a particular country, such as lower factor costs, easier access to the domestic market, or disadvantages faced by foreign firms importing into that market. This compels companies to go beyond these basic benefits and develop more lasting and robust competitive advantages. [4]

Diamond as a System

Each of these four factors – Demand Conditions, Factor Conditions, Related and Supporting industries, and Firm Structure, Strategy and Rivalry – represents a corner of the *Diamond*, and the impact of one often relies on the state of the others. For instance, having sophisticated customers will not lead to the creation of advanced products unless the workforce is skilled enough to fulfil these customer needs. Similarly, disadvantages in certain production factors will not drive innovation unless there is strong competition and company objectives that encourage long-term investment. Overall, a weakness in any of these determinants limits an industry’s capacity for growth and upgrading. However, these points of the diamond are interconnected and reinforce each other, forming a system. Two aspects in particular – Domestic Rivalry, which encourages improvement across all determinants and Related and Supporting industries, which enhances and intensifies the interaction among the four factors – have significant power to transform the *Diamond* into a cohesive and dynamic system.

The role of domestic competition demonstrates how the diamond framework functions as a self-reinforcing system. Strong local rivalry encourages the creation of distinctive pools of specialised resources, especially when competing firms are based within the same city or region. For example, the University of California at Davis has emerged as the world's top centre for wine-making research, working closely with California's wine producers. Active local competition also enhances domestic demand within an industry. In sectors like furniture and footwear, Italian consumers have come to expect higher quality and more innovative products due to the rapid pace of new product development driven by intense rivalry among hundreds of Italian firms. Domestic rivalry further supports the growth of related and supporting industries. Japan's globally leading group of semiconductor companies, for instance, has given rise to Japanese firms that are top producers of semiconductor equipment. This effect operates in multiple directions: world-class suppliers may enter the industries they supply, or sophisticated buyers may themselves enter supplier industries, especially when they have relevant expertise and see the new industry as strategically important. For example, in Japan's robotics sector, Matsushita and Kawasaki originally developed robots for internal use before selling them commercially, and today they are strong players in robotics. In Sweden, Sandvik expanded from specialty steel into rock drills, while SKF moved from specialty steel into ball bearings.

Formation of Clusters

Another impact of the diamond's systemic nature is that countries typically do not host just a single competitive industry; instead, the diamond fosters environments that give rise to clusters of competitive industries. These industries are not randomly scattered throughout the economy but are generally linked via vertical relationships (buyer-seller connections) or horizontal relationships (shared customers, technologies, or distribution channels). Clusters also tend to be geographically concentrated rather than dispersed. One competitive industry often paves the way for another, creating a mutually reinforcing cycle. For example, Japan's dominance in consumer electronics drove its success in semiconductors, particularly memory chips and integrated circuits used in these products. Japan's strength in laptop computers, in contrast to its limited success in other segments, stems from its expertise in compact, portable products and its advanced liquid crystal display technology, developed initially for calculators and watches. Once a cluster emerges, all the industries within it support each other. Benefits flow in every direction – forward, backward, and horizontally. Intense competition in one industry spreads throughout the cluster through spin-offs, bargaining power, and diversification by established companies. Entry from other industries within a cluster encourages improvement by increasing the variety of approaches to research and development and by enabling the adoption of new strategies and skills.

Because suppliers and customers interact with several competing firms, information flows easily throughout the cluster, allowing innovations to spread quickly. Unexpected connections within the cluster often reveal new competitive methods and business opportunities. As a result, the cluster serves as a means to maintain diversity and counteract the inward focus, stagnation, rigidity, and complacency among competitors that can otherwise hinder or prevent further competitive progress and new entrants. [4]

Two more factors can significantly impact a nation's system and are essential to fully explain the theory: Chance and Government. Interestingly, Porter's original article on "Competitive Advantage of Nations" published in Harvard Business Review did not include these two factors, but when he expanded the article into a book, he incorporated them.

Chance

Chance events refer to occurrences beyond the control of companies (and often beyond the nation's Government as well), such as major inventions, fundamental technological breakthroughs, wars, international political changes, and significant shifts in foreign market demand. These events create disruptions that can alter or reshape industry structures, giving firms from one country the chance to overtake competitors from other nations. Such events have been crucial in changing competitive advantages across various industries.

Role of Government

In the ongoing discussion about national competitiveness, the Government's role is one of the most debated yet least understood topics. Some people view Government as a crucial supporter of industries, using various policies to directly enhance the competitiveness of specific strategic sectors. Others believe in a pure "free market" approach, arguing that the economy should operate solely through market forces without Government intervention. However, both these perspectives are flawed. If taken to their extremes, either approach would eventually undermine a country's competitive strength. The true role of Government is to act as a catalyst and motivator, pushing companies to aim higher and achieve better competitive performance, even if this process is challenging and uncomfortable. Government alone cannot build competitive industries; only companies can achieve that. The Government's impact is effective only when it works alongside the favourable conditions described in the diamond model. Nevertheless, Government has a powerful role in reinforcing and transmitting these forces.

Policies that are successful are those that create an environment conducive to competitive advantage, rather than involving the Government directly in business activities—except in countries that are still in the early stages of development. Essentially, the Government's role is indirect rather than direct.

Usually, it takes an industry more than ten years to build a competitive advantage. This process involves gradually improving human skills, investing in products and production methods, forming industry clusters, and entering foreign markets. For example, Japanese automobile companies began their initial, hesitant exports in the 1950s but only established strong global positions by the 1970s. However, in the political arena, a decade feels like an eternity.

As a result, most governments prefer policies that yield visible short-term benefits, such as subsidies, protectionist measures, and orchestrated mergers – policies that actually hinder innovation. The policies that could truly create long-term improvements are often too slow to show results for impatient politicians or, worse, involve short-term hardship.

For instance, deregulating a protected industry may initially lead to bankruptcies but will ultimately result in stronger and more competitive firms. Policies that provide temporary, static cost advantages but unintentionally weaken innovation and growth are among the most frequent and significant mistakes in government industrial strategy. In their attempt to support industries, governments often adopt measures like joint projects to avoid "wasteful" R&D spending, which actually suppresses competition and dynamism. Yet, even a 10% cost reduction through economies of scale can quickly be offset by rapid improvements in products and processes and by seeking higher production volumes in global markets – outcomes that such policies often obstruct.

When strict regulations anticipate standards that will eventually become global, they provide domestic companies with an early advantage in creating products and services that will be in demand internationally. For instance, Sweden's rigorous environmental protection standards have given its industries a competitive edge. Atlas Copco, for example, manufactures low-noise compressors that can operate in crowded urban areas without disturbing residents. However, such stringent standards need to be paired with a fast and efficient regulatory process to avoid wasting resources or causing delays.

There should be strong restrictions on direct collaboration between industry competitors. Currently, one of the most popular global policy trends in the area of competitiveness is the push for increased cooperative research and industry consortia. This trend is based on the belief that independent research by competing firms is wasteful and duplicative, that working together leads to economies of scale, and that individual firms often underinvest in R&D because they cannot capture all the resulting benefits. As a result, governments have promoted greater direct collaboration. However, the most beneficial collaborative projects are usually those that span multiple industries and require significant R&D investments. Governments should also encourage goals that drive continuous investment. They play a crucial role in shaping the objectives of investors, managers, and workers through their policies. For example, the way capital markets are regulated influences investor incentives, which in turn affects how companies behave.

The government should focus on promoting continuous investment in developing human skills, fostering innovation, and building physical assets. One of the most effective ways to increase long-term investment in industry is to offer tax incentives for capital gains held over a long period (five years or more), but only for new investments in corporate equity, pension funds and tax exempt investors.

Regulating competition with measures like creating government monopolies, restricting entry into industries, or setting prices has two major negative effects. It suppresses competition and innovation because companies focus more on complying with regulators and protecting their existing positions than on improving. Additionally, it makes the industry less dynamic and a less attractive buyer or supplier. However, deregulation and privatisation alone are not enough to ensure success; they must be accompanied by strong domestic competition, which in turn requires a firm and consistent antitrust policy. Strict enforcement of antitrust laws is crucial, particularly regarding horizontal mergers, alliances, and collusive practices, as this forms the basis for innovation. Although it is currently popular to support mergers and alliances under the banner of globalisation and creating "national champions," these often weaken a nation's competitive advantage. True national competitiveness demands that governments block mergers, acquisitions, and alliances involving industry leaders. Moreover, the rules for approving mergers and alliances should be applied equally to both domestic and foreign firms.

In conclusion, government policies should prioritise new market entrants, both local and international, over acquisitions. Mergers within related sectors can be permitted if they facilitate the transfer of skills and create competitive advantages. Managed trade, instead of fostering innovation within a country's industries, merely secures markets for inefficient firms. Trade policy should focus on ensuring open access to foreign markets. For it to be effective, trade policy cannot remain passive; it should not only react to complaints or favour industries with strong political influence, nor should it require extensive evidence of harm or be limited to struggling sectors. Instead, trade policy should aim to open markets wherever the nation has a competitive edge and should proactively address emerging industries and potential issues. Tariffs that penalise firms for unfair trading practices are a better option than setting market quotas. Another increasingly effective method to open markets is to restrict companies from countries with unfair practices from investing in acquisitions or establishing production units domestically, thus preventing them from using their unfair advantages to gain a foothold immune to sanctions.

Companies themselves should actively embrace pressure and challenges rather than shy away from them. An important part of strategy is to leverage the home environment to drive innovation. This can be achieved by targeting the most sophisticated and demanding customers and distribution channels, serving buyers with the most challenging needs, setting internal standards that surpass the strictest regulations, sourcing from the most advanced suppliers, and treating employees as long-term assets to encourage skill development and productivity growth. Firms should view their most capable competitors as motivation. Strong rivals and respected competitors can serve as a unifying force to drive organisational change. The best managers always remain slightly cautious; they closely observe and respect their competitors. To maintain dynamism, companies should embed the pursuit of challenges into their organisational culture. For instance, if a company lobbies against strict product standards, it signals a lack of ambition from leadership. Firms that prioritise stability, compliant customers, dependent suppliers, and weak competitors are setting themselves up for stagnation and eventual failure.

Companies should set up early warning systems to detect potential opportunities ahead of time. By identifying these opportunities early, a company can enter the market before others or among the first few and gain the benefits of being an early mover. Such systems also help prevent important data and information from being filtered out at different organisational levels.

To stay ahead, companies can take proactive steps to notice and act on signs of change before competitors do. For instance, they can target customers whose needs hint at future market trends; explore new emerging customer groups or distribution channels; operate in areas where regulations are likely to spread to other regions; include external experts in their leadership team; and build strong connections with research institutions and sources of skilled talent.

Companies have a crucial interest in improving their domestic environment to better support international success. It is part of their responsibility to actively contribute to building industry clusters and to collaborate with local customers, suppliers, and distribution channels to help them enhance and expand their own competitive strengths. For instance, to strengthen domestic demand, Japanese musical instrument makers like Yamaha, Kawai, and Suzuki have set up music schools. Likewise, companies can motivate and assist local suppliers of key specialised inputs, including encouraging them to compete on a global scale.

To compete on a global scale, a company requires strong local competitors and intense domestic competition. Nowadays, particularly in the U.S. and Europe, managers often complain about excessive competition and advocate for mergers and acquisitions to achieve perceived economies of scale and critical mass. Although such complaints are understandable, their reasoning is flawed. Strong domestic rivalry actually builds sustainable competitive advantage. Furthermore, expanding internationally is preferable to simply dominating the home market. If a company seeks an acquisition, it is generally wiser to acquire a foreign firm that can accelerate global expansion, enhance domestic strengths, or compensate for domestic weaknesses rather than merging with major local competitors.

Globalise to access unique advantages in other countries**.** In pursuit of "global" strategies, many companies today abandon their home-based competitive strengths. While adopting a global outlook is crucial for creating competitive advantage, depending on foreign operations that replace domestic capabilities is always a less effective choice. It is better to innovate to overcome local disadvantages than to outsource production, and fostering local suppliers and customers is preferable to relying entirely on international ones.

One of the most crucial decisions for multinational firms is choosing which country will serve as the home base for each of their individual businesses. A company may establish different home bases for its various divisions or segments. Ultimately, competitive advantage is built in the home country, as this is where strategies are formulated, core product and process technologies are developed, and significant production capacity is established. The conditions within the home nation must foster innovation; if they do not, the company will be forced to relocate its home base to a country that encourages innovation and offers the most favourable environment for global competitiveness. There is no middle path in this – the management team must relocate as well.

Many companies and their top leaders misunderstand the nature of competition and their true responsibilities, focusing narrowly on improving financial performance, seeking government support, pursuing stability, and reducing risk through mergers and alliances. However, today's competitive landscape requires strong leadership. True leaders believe in driving change; they motivate their organisations to innovate continuously and understand the critical role their home country plays in their competitive strength, actively working to enhance it. Most importantly, effective leaders recognise the importance of pressure and challenge. Because they are willing to support necessary yet difficult government policies and regulations, they often earn the reputation of being "statesmen," even if they do not see themselves that way. They are ready to give up comfort for challenges, leading to lasting competitive advantage. This should be the ultimate aim for both nations and companies: not merely surviving, but achieving and sustaining international competitiveness over time. [4]

Competitiveness of India's Nuclear Power Industry

Porter's theory is valid with reference to industrial competitiveness and is found as most appropriate theory to test any kind of industry including nuclear industry.

The research has been carried out by using the application of Porter's Diamond Model. It is an analytical work that encompasses the four diamond and two extra factors that engages with the systemic and dynamic aspects of Porter's theory. It is a complete analysis work in which the sub components of each *Diamond* are identified, analysed and also the working of the *Diamond* is analysed. Hereafter, the words determinants and *diamond* are used interchangeably.

The analysis has been carried by first identifying the existence of sub components of each *Diamond*. Then the level of presence will be identified by assigning numeric values. The total of numeric values will reveal if a particular D*iamond* is exiting or not. The approach is given as follows:

a. To identify the presence of sub components of each *Diamond.*

b. Each sub component level has been assessed by using following pointer scale*:*

3 – Strongly present
2 – Somewhat present
1– Present in basic level
0 – Not present

c. Presence or absence of a *Diamond* has been identified by the total of sub components i.e. more number of sub components and higher total values of sub components indicates that particular *Diamond* is available. The following diagram provides a pictorial representation of our approach.
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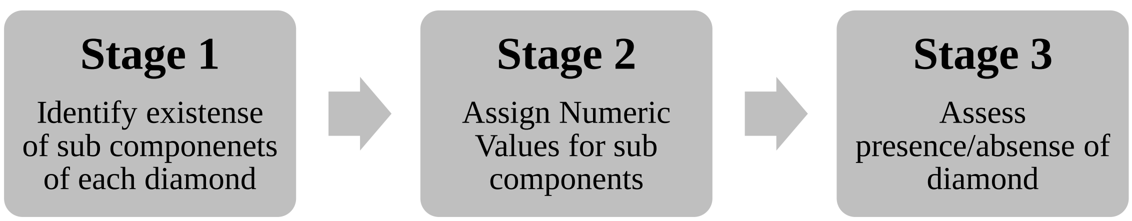

Figure 4.2: Approach for Assessing the Presence of Diamonds

This approach not only identifies the determinants but also evaluates if the *Diamond* is functioning or not. Hence, functioning of the diamond has been evaluated in next part of the analysis. Here the relationship between the *Diamond* Components will be studied and the influence of each *Diamond* Component in creating or improving the other *Diamond component* will be analysed.

CHAPTER 5: RESULTS

Assessment of Presence of Determinants

The sub components for each determinant are tabulated and their presence is marked by answering ‘yes’ or ‘no’. If the answer is ‘yes’ then as a next step its “level of presence” is identified by answering to the pointer scale.

Figure 5.1: Assessing the Presence of Determinants provides a summary of the analysis, evaluating the presence of various determinants. The colour Green is used to indicate ‘Adequately Present’, Orange is used to indicate ‘Weakly Present” and Red is used to indicate ‘Not Present’. It can be seen that Indian nuclear industry has *Factor Conditions* and *Demand Conditions* as ‘Adequately Present’ but *Related and Supporting Industries* are ‘Weakly Present’ and *Firm Structure, Strategy and Rivalry* is not in existence. Opportunities of “Positive” *Chances* are available. The role of the *Government* can be more strong and comprehensive.

Factor Conditions

Table 5.1: Analysis of Factor Conditions

S. No	Sub component (Porter Model)	Sub component (India’s Nuclear Industry)	Presence Yes/No	Level of presence 3/2/1
1	Human resources	Human resources	Yes	3
2	Physical resources	Physical resources	Yes	3
3	Knowledge resources	Knowledge resources	Yes	2
4	Capital resources	Fund availability and alternative sources of income	Yes	1
5	Infrastructure	Infrastructure	Yes	2
	Total			11

Score : 11/15

- Human Resources

Porter's theory considers that human resources which has the quantity, skills, and cost of personnel (including management). India's biggest strength is its human resource with 65% of our population below the age of 35 years [16]. According to "*knowledge@wharton*", while the global economy will experience a skilled manpower shortage, India will be one of the few countries in the world with a working-age population that exceeds its number of retirees [17].

With the opening up of Indian economy in 1990s and due to the Information Technology (IT) Information Technology enabled Services (ITeS) revolution, India has transformed itself from an agricultural society to a knowledge society and is building knowledge capital for the world.

On the nuclear industry front, Indian nuclear industry was started because of the efforts of the scientist Dr. Bhabha. Right from the inception, India had good number of scientists and technicians and this number is steadily growing. Since independence the country had one of the largest pools of scientists and technicians in nuclear field. As of 2024, Nuclear power Corporation of India Limited (NPCIL) alone has employee strength of about 11,118 employees [18]. With a young population and constant growth in nuclear scientists and technicians, India has a complete advantage in human resource. Hence, in case of Human Resources rating is "3 - strongly present".

- Physical Resources

Physical resources consists of abundance, quality, accessibility, and cost of the nation's land, water, mineral or fuel deposits, raw material and other physical traits. Factors like climatic conditions, location and time zone are also grouped here. India has considerable physical resources for nuclear power industry.

India has modest Uranium resources and as of November, 2017, Atomic Minerals Directorate for Exploration and Research (AMD) has established 104042 tonnes of uranium reserves [19].India's Uranium reserves are sufficient for the stage I(PHWR) and subsequent stages of the three stage programme.

India possesses considerable quantity of Thorium. As per the Press Information Bureau report dated 27th November 2014, Atomic Minerals Directorate for Exploration and Research (AMD) has so far established 11.93 million tonnes of in situ resources Monazite (Thorium bearing mineral) in the country, which contains about 1.07 million tonnes of Thorium. India's stage 3 stage Nuclear programme is based on the physical resources available in the country. Hence, on the front of physical resources rating is considered as "3 - strongly present". [20]

- Knowledge Resource

Knowledge resources are found in various places such as universities, government research institutes, private R&D facilities, government statistical offices, business and scientific publications, market research reports, databases, and trade associations. In India, the Department of Atomic Energy (DAE) oversees research related to atomic energy. To achieve these objectives, the DAE has set up its own research and development centres and grant-in-aid institutions, incorporating several pre-existing institutes under its fold. Collectively, these institutions under DAE form a strong network with significant expertise in science, engineering, and research infrastructure.

India began its efforts early, establishing a training school at BARC in 1957. Later, in 2005, the Homi Bhabha National Institute (HBNI) was formed to integrate nuclear training and research within a single organisation. HBNI unites ten leading institutions under DAE, known as Constituent Institutions (CIs), creating a cohesive, research-focused framework.

Additionally, the Nuclear Power Corporation of India Limited (NPCIL) operates its own training centres near nuclear plant sites. These centres provide most of the training for technical staff without degrees as well as for newly recruited engineering graduates and other technical personnel.

Recently Indian universities (both run by Government and private) are also offering engineering courses in nuclear area. Apart from this, Indian nuclear scientists take part in the training programmes organised by IAEA and also visit other countries for knowledge and skill upgradation activities. Indian students also go to foreign universities for higher studies in nuclear field.

Next to educational institutions and research centres, the number of patents filed is one of the determinants of the knowledge resource. In India, no individual can file for patent in the invention relating to atomic energy. This is prohibited under Patents Act 1970 as well as Atomic Energy Act 1962. However research institutions of India have filed and obtained patents. Since 1980 Department of Atomic Energy has filed only 270 patents. [21]

In spite of these efforts, still the knowledge resource is considered as "2 – somewhat present", mainly on account of two reasons: a) Number of educational institutions are relatively low ; b) Number of patents filed by India are also considerably low.

- Capital Resources

Capital resources represent the amount and cost of capital available to finance industry. The Government of India funds all nuclear projects and institutions. Nuclear industry is unique in the sense, for this industry, raw material cost is low but the set up cost or infrastructure cost is so high.

India had negotiated with Russia for supply of reactors as well as for the funding also [22]. On this background, Indian nuclear industry has also failed to identify alternative sources of capital rather than fully dependent on funding by Indian Government. Thus it is given as “1 – present in basic level” for capital resources.

- Infrastructure

Availability, type, quality and user cost of infrastructure is considered here. Porter considers aspects such as transportation system, communications system, mail and parcel delivery, payments or funds transfer, health care, housing stock and cultural institutions, which affect the quality of life and the attractiveness of a nation as a place to live and work.

From the time of Independence, the infrastructure facilities in India have considerably improved. India has been considered as one of the attractive destination for investment. Still the spread of infrastructure facilities across the nation is not uniform; hence it is given as “2 – somewhat present” for infrastructure.

Demand Conditions

Table 5.2: Analysis of Demand Conditions

S. No	Sub component (Porter Model)	Sub component India’s Nuclear Industry	Presence Yes/No	Level of presence 3/2/1
1	Home demand composition	Demand nature, mix, composition and demanding buyers	Yes	2
2	Demand size and pattern of growth	Demand for source of electricity	Yes	3
3	Internationalisation of domestic demand	Nuclear power usage for electricity purpose	Yes	3
	Total			8

Score 8/9

- Home Demand Composition

Home demand composition is about the nature, character and mix of home buyers. This becomes a competitive advantage provided the home demand gives clearer or earlier picture of buyer needs and the home buyers are demand putting pressure on the firms to innovate.

The distribution companies are the final user of Nuclear Power. Both Government and Private distribution companies are buyers for electricity produced from the Nuclear Plant. Power Distribution in cities including New Delhi and Mumbai is done by private companies while State distribution companies provide distribution in other states of the country. Privatisation of distribution companies is on the rise and private companies are demanding buyers. However, we still have a long way to go for our state owned distribution companies to become demanding buyer.

Hence, we will give a rating of “2- somewhat present” in the home demand composition aspect.

- Demand Size and Pattern of Growth

Generally larger home market is an advantage, but Porter also highlights that limited home market can force companies to export, giving avenue for new markets and geographical expansions. Next to size of the demand, the crucial factor is the rate at which the demand is growing, higher the growth rate, better the advantage.

In 2023, India ranks third in the world in domestic electricity consumption with 1986 TWh electricity consumed. The growth rate of electricity production during 2000-2023 was 254% [23] .In fact, Dr. Bhabha’s logic for the development of the Indian atomic energy programme was founded in the belief that as the country was not sufficiently endowed with resources of conventional fuel, development of nuclear energy sources for power production was vital.

India is growing fast. Energy is central to achieving India’s development ambitions, to support an expanding economy, to bring electricity to those who remain without it, to fuel the demand for greater mobility and to develop the infrastructure to meet the needs its citizens. According to Bridge to India study, India will require almost 4041 TWh of electricity by 2035 [24] . The vast electricity requirement can only be met by adding new plants using all means of generation namely Nuclear, Coal, Hydro, Gas, Solar, Wind etc. International Energy Agency’s India Energy Outlook projects that over 50% of new generation capacity to 2040 comes from renewables and nuclear. Currently, nuclear sector contributes about 2% of India’s total power stations installed capacity (8180MW out of 475212 MW). [25]

At present, apart from coal and hydrocarbon, nuclear energy is the only alternative available which could support the base load operation of grid and shorten the increasing gap between energy demand and supply. Firstly long term demand cannot be met by fossil fuel, secondly it limits greenhouse gas emission, thirdly it would use the large amount of Thorium reserves that the country is endowed with and lastly it offers long term options to develop alternative energy systems.

The size of demand and the growth rate offers tremendous potential to India's nuclear sector to increase the share in future.

For India, on electricity front the demand and growth rate are higher providing a stronger advantage with the rating of "3 - strongly present".

- Internationalisation of Domestic Demand

By internationalisation of domestic demand, Porter means how much the demand for the product or service is created in other countries and it pulls the nation's product or service abroad. Pizzas, credit cards are good example for this category wherein the product or service was originated in one country but later on people in other countries are also started to use them thus creating demand outside home country.

In the case of nuclear power generation, internationally there is increasing demand for nuclear power due to growing thrust on clean energy and base load support for the grid *(which cannot be fulfilled by solar, wind power).*

Though nuclear science is universal still countries require support and assistance in terms of training for personnel, nuclear materials, equipment for reactors etc. Countries supporting each other in the nuclear field are not uncommon. U.S.A had supported U.K in developing U.Ks nuclear programme, U.S.S.R had supported China. India received support and assistance mainly from U.S.A, Canada and Russia.

When countries import nuclear technology for electricity generation, multiple and detailed safeguards are imposed to ensure no deviation takes place towards weapon programme.

The demand for nuclear power is rising, driven by growing economic activities in developing and underdeveloped countries. Compared to the worldwide nuclear operational capacity of 372 GW at the end of 2023, the low scenario anticipates a rise of approximately 40%, reaching 514 GW by 2050. Under the high scenario, global nuclear capacity is expected to expand to 2.5 times its present level, attaining 950 GW by 2050. [26]

This growth is driven by concerns over energy security and the need to reduce greenhouse gas emissions, encouraging the development of additional nuclear capacity.

Expansion plans are not limited to existing nuclear power-using countries; many new countries are also planning to establish nuclear power plants. The World Nuclear Association notes that over 45 countries are actively considering starting nuclear power programmes, with UAE, Turkey, Vietnam, Belarus, and Poland leading the way. A detailed geographic breakdown of these emerging countries follows.

Table 5.3: Emerging Nuclear Power Countries [27]
Source: world-nuclear.org

Region	Countries
Europe	Albania, Serbia, Croatia, Norway, Poland, Estonia, Latvia, Lithuania, Ireland, Turkey
Middle East and North Africa	Gulf states including Saudi Arabia, Qatar, Kuwait and Iraq; Yemen, Israel, Syria, Jordan, Egypt, Tunisia, Libya, Algeria, Morocco, Sudan.
West, Central, and Southern Africa	Nigeria, Ghana, Senegal, Kenya, Uganda, Tanzania, Zambia, Namibia, Rwanda, Ethiopia.
Central and South America	Cuba, Chile, Ecuador, Venezuela, Bolivia, Peru, Paraguay.
Central and Southern Asia	Azerbaijan, Georgia, Kazakhstan, Mongolia, Bangladesh, Sri Lanka, Uzbekistan.
South East Asia and Oceania	In Southeast Asia and Oceania: Indonesia, Philippines, Vietnam, Thailand, Laos, Cambodia, Malaysia, Singapore, Myanmar, Australia.

India is one of the early starters of using nuclear energy for civilian electricity purpose and the country can also make use of export opportunities for nuclear reactors and related electricity generation services to other countries. Hence, internationalisation of demand is rated as “3-strongly present” on the basis of usage of nuclear energy by other countries for electricity generation purpose.

Related and Supporting Industries

- Competitive Advantage in Supporting Industries

Having internationally competitive supplier industries within a country provides several benefits to its downstream sectors. In the case of the nuclear power industry, key supplier sectors include heavy engineering *(for manufacturing steam generators and turbines),* the construction industry *(for building power plants),* steel production *(as raw material),* and the instrumentation industry *(for plant control systems).* While India possesses these supplier industries, they are not global leaders in their respective fields, and therefore, the Indian nuclear sector lacks the benefits that come from having highly competitive domestic suppliers. Hence, rating given as "1 – present in basic level".

Table 5.4: Analysis of Related and Supportive Industries

S No	Sub component (Porter Model)	Sub component India's Nuclear Industry	Presence Yes/No	Level of presence 3/2/1
1	Competitive advantage in supplier industries	Heavy Engineering, Construction, Steel, instrumentation etc.	Yes	1
2	Competitive advantage in relative industries	Power transmission, Power distribution	Yes	1

Score:2/6

- Competitive Advantage in Related Industries

The existence of competitive related industries within a country often paves the way for the emergence of new competitive sectors. Related industries are those where companies can coordinate or share value chain activities, or where their products are complementary. In the electricity sector, power distribution and transmission are such related industries. However, India lacks a notable competitive edge in these areas as well. Hence, rating given as "1 – present in basic level".

Firm Strategy, Structure and Rivalry

- Strategy and Structure of Domestic Firms

Regarding this fourth and final element of the diamond, Porter states that no single management system fits all situations. However, countries are more likely to excel in industries where the management styles and organisational practices supported by their national environment align with the sources of competitive advantage in those industries. For the nuclear sector, organisations require high levels of confidentiality, swift decision-making, strong risk-taking capacity, a sense of ownership and responsibility, minimal bureaucracy, and a culture focused on research and development.

Indian nuclear industry lacks in most of these aspects. Hence, the competitive advantage is not available for Indian nuclear power industry. Hence, rating given as “0 – Not Present”.

Table 5.5: Analysis of Firm Strategy, Structure and Rivalry

S. No	**Sub component (Porter Model)**	**Sub component – for India’s Nuclear Industry**	**Presence – Yes/No**	**Level of presence - 3/2/1**
1	Strategy and structure of domestic firms	Secrecy, quick decision making, R&D culture, risk taking, ownership for decisions	No	0
2	Goals	Alignment of organisational goals and individual motivation factors	No	0
3	Domestic rivalry	Rivalry among the firms in the in the industry	No	0

Score:0/9

- Goals

Nations will succeed in industries where the goals of companies and motivations for employees are aligned with the sources of competitive advantage. More broadly, nations succeed in industries where there is unusual commitment and effort from workforce.

Indian IT/software industry is an apt example for synchronisation of company goals and individual motivation factors. A job in IT/software industry has many advantages in terms of lucrative salary, prestige and recognition in society, opportunity for foreign exposure, chance of quick carrier growth etc. most of these were the goals of majority of work force and IT industry was able to attract cream of talent. There is a natural alignment of company goals with these motivational factors and created a strong competitive advantage. But in the case of Indian nuclear power industry there is no visible sync between motivational factors and goals. People working in the nuclear power are not motivated with the nuclear power addition goals as projects are delayed beyond timelines, cost overruns etc. Hence, resulting in no competitive advantage rating given as “0 – Not Present”.

- Domestic Rivalry

One of the key empirical insights from Porter's research is that intense domestic rivalry is closely linked to the development and maintenance of competitive advantage within an industry. While some argue that domestic competition is inefficient due to duplicated efforts and reduced economies of scale, Porter suggests that the common solution has been to support one or two firms as national champions, giving them the scale and capability to compete globally, or to encourage collaboration among firms. However, in the Indian nuclear power sector, there is no domestic competition. The power generation plants are solely operated by NPCIL, a Government of India enterprise. Hence, rating given as "0 – Not Present".

Chance

Porter notes that in the history of most successful industries his team studied, chance events also played a significant role. These are unpredictable occurrences, often beyond the control of firms or even national governments. Chance events matter because they disrupt existing competitive positions, potentially removing the advantages held by established industries and giving new industries from different nations an opportunity to gain competitive advantage under the changed conditions.

Some key events that can strongly influence competitive advantage include:

- Increasing global concern about CO2 and other Greenhouse gas emission.
- Technological Advancement of Small Modular Reactors SMRs offer potential advantages in terms of scalability, cost, and siting flexibility
- Data Centres and AI are increasing demand of electricity at a rapid rate.

Role of Government

According to Porter, though it is tempting to make Government as the fifth determinant, yet this is neither correct nor the most useful way to understand Government's role in international competition. Government's real role in national competitive advantage is in influencing the four determinants. Government can influence (and be influenced by) each of the four determinants either positively or negatively. If the influence is positive it can create competitive advantage. Now, let us analyse the role of Government in Indian nuclear industry. Role of Indian Government is unique in multiple ways. The role has been, is and will be wide spread. The Government is the controller, decision maker, operator, investor of nuclear power industry. Role of the Government can be mainly seen in the areas of technology, plant operations, overall governance and international activities.

Overall Governance

Nuclear Power projects are handled by NPCIL *(Government of India Enterprise)* and most projects are delayed beyond timelines resulting in cost escalations. Government is not able to positively influence the Nuclear power Industry to complete the projects on time. Unlike most government bodies in India, NPCIL and other nuclear power entities do not report to cabinet but directly to the Prime Minister. This setup limits the ability of politicians, bureaucrats, or the general public to question the policies and operations of Nuclear Power Industry in India.

Similarly, the DAE often dismisses concerns over project cost escalations. For example, when the Manuguru Heavy Water Plant's costs rose by 133%, the CAG questioned this increase, but the DAE justified it by stating that the project's approval was based on strategic rather than commercial reasons. [28]

The Indian Government has consistently engaged in global nuclear affairs across all dimensions of nuclear energy. These international activities are related to nuclear trade and policy. India has signed agreements with other nations for the supply of nuclear materials and services. Due to its limited domestic enriched Uranium reserves, India continues to import Uranium and has also sourced reactors and technologies from abroad for its nuclear programme.

India was among the first countries to join the International Atomic Energy Agency (IAEA) in 1957. It holds a seat on the IAEA's Board of Governors, contributes substantial funds and technical expertise among developing nations, and has kept its reactors under IAEA safeguards for over thirty years. The IAEA's annual reports often praise India's reactor designs and safety standards.

In Union Budget 2025, Government assured for two key amendments to open the Nuclear Power sector to private and foreign players. First amendment is related to easing provisions of Nuclear Liability Law (CLNDA 2010) and Second amendment is related to Atomic Energy Act 1962 to allow private and foreign players *(with minority stake)* to enter Nuclear Power sector as operators of plant. These amendments are yet to be tabled in parliament and Government pro activeness is required to positively influence the Nuclear power Industry.

Despite the Government's continuous involvement, its efforts have not been sufficiently strong or proactive. There is a need for the Government to take more active measures in building competitive advantages and addressing the gaps highlighted by the four determinants in Porter's Diamond model.

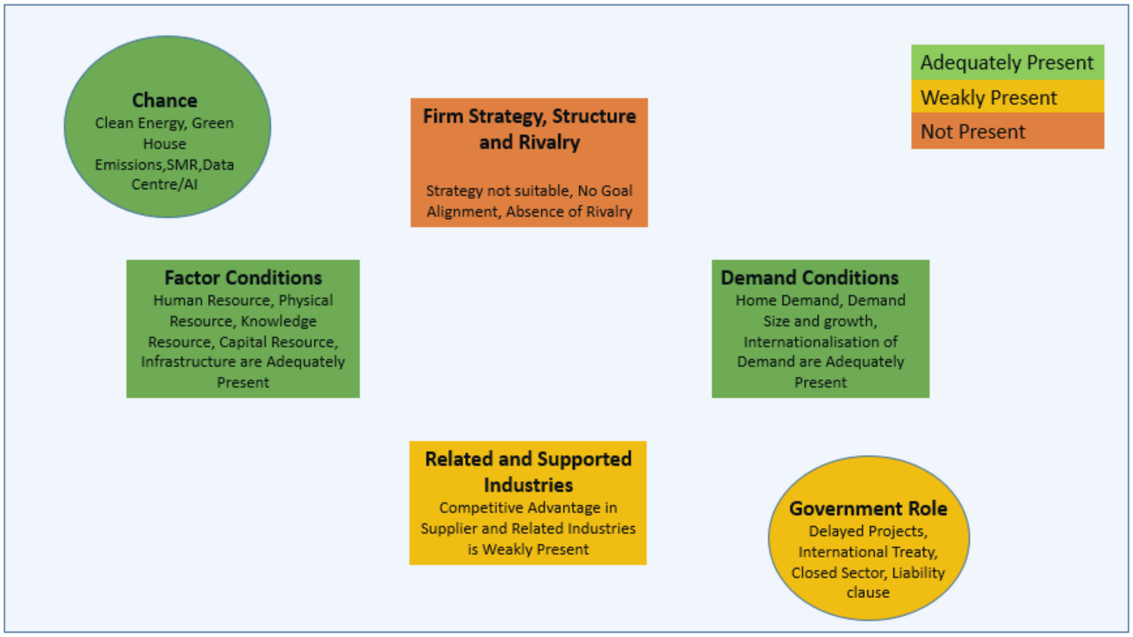

Figure 5.1: Assessing the Presence of Determinants

Assessment of Functioning of Diamond

The initial part of the analysis revealed that two determinants are adequately present and one determinant is weakly present and one factor is not present in India's nuclear sector. This section of the analysis aims to assess whether the *"Diamond"* framework is actually functioning or not. As per Porter, these determinants indicate how conducive the national environment is for fostering competitiveness. The Diamond, which captures multiple diverse aspects of a country, evaluates how effectively the nation generates and transfers these forces, along with possessing the necessary insights and tools for building competitive advantage.

The individual determinants shaping the national environment are interlinked, as the impact of one often relies on the condition of others. For instance, having discerning buyers will not result in advanced products unless the human resource quality is adequate to cater to buyer demands. Similarly, certain factor disadvantages will not drive innovation unless there is robust competition and company objectives encourage consistent investment. Overall, a weakness in any single determinant can limit an industry's scope for progress and development.

Diamond could not function well in India's nuclear industry as one component is not present and one component is weakly present. Hence the *Diamond* is incomplete and partly functioning. Major reasons for partly functioning of diamond includes domestic rivalry and benefits passed by competitive supportive industries are absent. Because of incomplete *Diamond*, the chances available could not be fully exploited immediately. Despite the Government's continuous involvement, its efforts have not been sufficiently strong or proactive to create competitive advantage. The individual determinants could not create a productive environment for the nuclear industry to boost its Competitiveness. It can be summarised that the *Diamond* is incomplete and competitive advantage of India's nuclear industry is limited. The next diagram explains the partial functioning of *Diamond.*

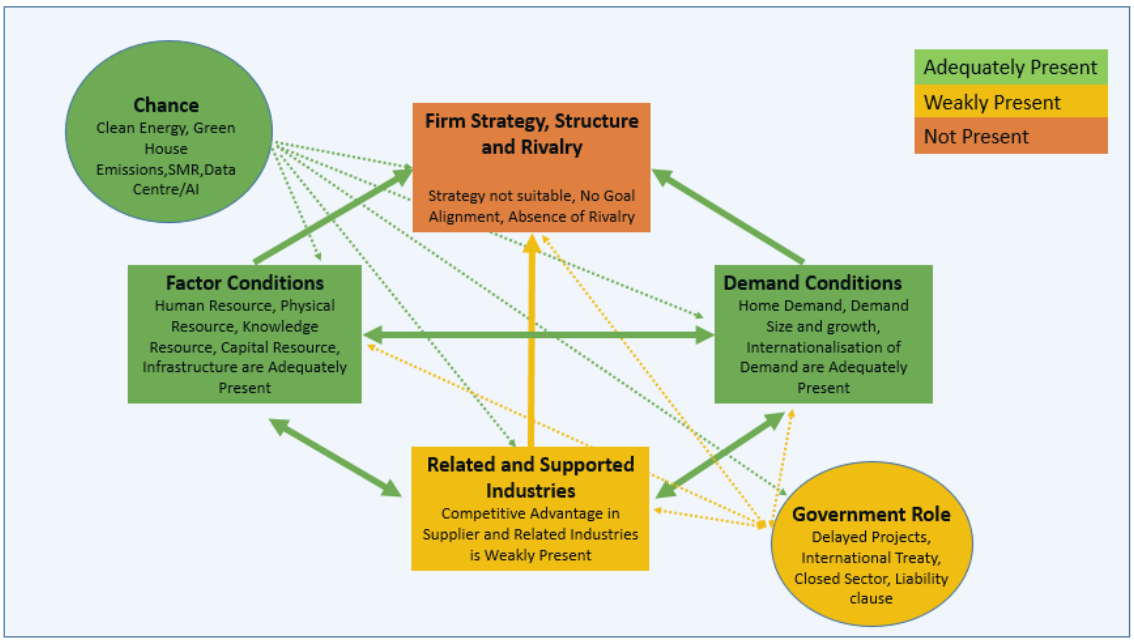

Figure 5.2: Analysis of Functioning of Diamond

CHAPTER 6: CONCLUSIONS

From the analysis it is found that India's nuclear industry's competitiveness is limited. It has two *Diamond components* namely *factor conditions* and *demand conditions* which are strongly present, one component namely *Related and supporting industry* as weakly present and remaining one component namely Firm Strategy Structure Rivalry is not present. The following table provides numerical analysis of the findings.

Table 6.1: Diamond Components Score Analysis

S. No	Diamond Component	Numerical score from analysis	Numerical score from analysis (%)	Remarks
1	Factor conditions	11/15	73.33%	Adequately Present
2	Demand conditions	8/9	88.88%	Adequately Present
3	Firm strategy, structure and rivalry	Nil	Nil	Absent
4	Related and supporting industry	2/6	33.33%	Weakly Present

By assigning equal weights to all the four factors i.e. 25% weightage for each factor and applying it on the numerical analysis score, the overall value comes to 48.89%. As the overall score is below 50%, it can be said that the competitiveness of India's nuclear industry is limited. The table on weighted analysis is presented as follows;

Table 6.2 : Weighted Average Analysis of Diamond Components

Diamond Component	Analysis score	Weightage	Weighted value
Factor conditions	73.33%	25%	18.33%
Demand conditions	88.88%	25%	22.22%
Firm strategy, structure and rivalry	0.00%	25%	0.00%
Related and supporting industry	33.33%	25%	8.33%
Total		100%	48.89%

India's nuclear programme is considered to be sixth best in the world and the county has got the fourth largest scientific manpower pool in the world. Still the competitiveness of the nuclear industry is limited. This is a major as well as a serious issue. The Nuclear Industry Innovation needs to be promoted so that high level of factors can be created that are specific to nuclear industry. At present, India has entered into second stage of three staged strategy of Dr. Bhabha H. J. This is the right time where multiple possibilities and opportunities are available for innovation and creating factor advantage which are applicable for nuclear industry.

The Government of India needs to be a demanding buyer by making its other departments/institutions/undertakings to perform more efficiently. The Government needs to promote supporting industries. Now more private sector players are keen to enter into nuclear market. The Government can make better use of this wave to create supporting industries and in turn they become leading players in Nuclear Power Supporting Industries so that Indian nuclear industry can gain advantage from it. The Government needs to follow a suitable style for management that creates competitive advantage and promote growth. With any one of these strong determinants being created the *Diamond* will function as a system and create/enhance other determinants.

This current situation is more apt as well as demanding for India to make its nuclear industry competitive. The research brings a different approach to the study Indian nuclear industry. Usage of time tested and universally proven model brings in objectivity to the study.

Summary of Major Findings:

- The competitiveness of India's Nuclear Power Industry remains limited.
- Indian Nuclear Power Industry's competitiveness is significantly hindered by the absence of domestic rivalry, and is moderately affected by the lack of supporting industries and the government's limited proactive approach.
- The study reveals that demand conditions and factor conditions positively influence the competitiveness of India's nuclear power industry.
- The study also indicates that there are ample opportunities and favourable conditions for the growth of India's Nuclear Power industry.

Recommendations:

- The sector should be opened to both public sector undertakings (PSUs) and private companies to enhance competition within the nuclear power industry.
- The supplier base from supporting industries should be strengthened through technology transfer agreements.
- Amendments to the Civil Liability for Nuclear Damage Act, 2010 are necessary, particularly regarding supplier liability in the event of an accident, to encourage greater supplier participation in the nuclear power industry.

Relevance for Research Audience:

- **Academicians:** The study demonstrates the application of a proven competitiveness framework to assess the nuclear power industry, providing a methodological reference for future academic research in similar sectors. The identification of limited competitiveness and influencing factors highlights research gaps that academicians can explore further, such as the role of domestic rivalry and supporting industries in enhancing sectoral competitiveness.
- **Managers:** The study enables managers to understand the factors influencing the competitive position of India's nuclear power industry and to explore partnerships, technology transfers, and supplier development initiatives to strengthen their supply chains. The findings equip managers with evidence to advocate for policy reforms with the government, such as opening the sector to private players and amending liability regulations, to create a more competitive and growth-oriented environment.
- **Government:** The study provides actionable insights for the government, especially regarding key aspects such as opening the sector to private players to enhance competition, amending the Civil Liability for Nuclear Damage Act, 2010 in relation to supplier liability, and adopting a more proactive approach to avoid project delays.

Limitation of the Study:

A major limitation of this project was the limited timeframe, which restricted the extent of data collection and analysis. Furthermore, the scarcity of previous research on the competitiveness of India's nuclear power industry constrained the ability to compare and validate the findings against existing literature.

Suggestion for Future Research: Considering the findings of this study, future research can focus on the following areas to further strengthen the competitiveness of India's nuclear power industry:

- Exploring Policy Reforms: Detailed studies can be undertaken to analyse the potential impacts of opening the nuclear sector to private players, including international case studies to recommend suitable policy frameworks for India.
- Strengthening Domestic Rivalry: Future research could examine strategies to foster domestic competition within the nuclear power industry, which may include analysing business models for public-private partnerships.
- Enhancing Supporting Industries: Further studies can assess the capabilities and readiness of supporting industries to integrate with the nuclear power supply

chain and propose initiatives for capacity building, skill development, and technology transfer agreements.

- Government Role and Proactive Measures: Research can focus on evaluating the effectiveness of existing government initiatives in the sector and suggest proactive measures to minimise project delays, including streamlining regulatory approvals and improving inter-agency coordination.
- Comparative International Studies: Conducting comparative studies with countries having competitive nuclear industries can provide actionable insights and best practices for India to adopt in enhancing its global competitiveness.

This work can be best considered as a stepping stone in effective Nuclear Power Management of India.

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