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# From Vision to Reality: Decoding India's Semiconductor Growth Factors

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**ABSTRACT:** While India has notable strengths in designing chips, it does not manufacture semiconductors domestically and is largely import dependent. This became a problem during the pandemic where shortages in the supply of chips slowed down manufacturing for key industries like automotives. Presently India lacks the high-grade production facilities required for large scale chip manufacturing. India's push to become a hub for semiconductor manufacturing is under way, but there is still a long way to go. This research is to identify factors influencing development of semiconductor chips manufacturing industry in India.

**Design/ Methodology/Approach** Grounded Theory & Analytical

KEYWORDS: Semiconductor, Chip Manufacturing, Policies, Factors

#### I. INTRODUCTION

The chip industry produces more transistors than all other companies combined. There is no sign of an end to the global chip shortage. As semiconductor demand increases, from automobiles to consumer electronics, techno-nationalists are calling for semiconductor supply chains to be self-sufficient.

India aims to become a global hub for semiconductor design, manufacturing, and technology development. As a result of the shortage of semiconductor chips, weaknesses in the semiconductor supply chain have been exposed and the need for increased domestic production has been highlighted [1].

Materials that exhibit conductivity among conductors and insulators are known as semiconductors. They can be pure elements, silicon or germanium or compounds, gallium, arsenide or cadmium selenide. Significance of Semiconductor Chips: They are the basic building blocks that serve as the heart and brain of all modern electronics and information and communications technology products. Increase in demand has been driven by the Covid-19 pandemic, which has highlighted the centrality of chip-powered computers and smartphones in people's lives. Due to its shortage, it causes cascading effects, since it creates pent-up demand that causes the subsequent famine [2,3].

A growing demand for digital devices and electronic products is expected to increase semiconductor demand in India to \$70-\$80 billion by 2026. In the next 4-5 years, India's share of global electronics manufacturing will increase from 3.5% to about 10%. Globally, the semiconductor industry is currently valued at \$500-600 billion, with a forecast of \$1 trillion (Figure-1) by 2030





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Fig 1. Semiconductor Industry Revenue

Using Indian-made processors offers more than just cost savings—it enhances autonomy in the electronics sector, reduces reliance on foreign technology, and mitigates digital security risks like backdoor vulnerabilities. While Indian teams have designed processors, no Indian company currently owns a commercially available microprocessor.

A homegrown processor could reduce imports and benefit electronics manufacturers by ensuring local design support, customization, and competitive pricing. The National Policy on Electronics 2019 (NPE 2019) aims to position India as a global Electronics System Design and Manufacturing (ESDM) hub, fostering chipset development and creating an enabling environment for industry growth.

India's electronics manufacturing has seen significant growth due to government initiatives and reforms. Domestic production escalated from INR 2,43,263 crore (USD 37 billion) in 2015-16 to INR 5,54,461 crore (USD 74.7 billion) in 2020-21, achieving a compound annual growth rate (CAGR) of 17.9%, propelled by a substantial market, proficient workforce, and economical labor costs.

able-1						(Values in Crore
escription	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
roduction*	2,43,263	3,17,331	3,88,306	4,58,006	5,33,550	5,54,461
nports**	2,68,105	2,87,559	3,40,901	4,01,450	3,85,081	3,99,374
xports**	39,064	39,980	41,220	61,908	82,929	81,822
ource: *Figure	s are shared l	by industry ass	ociations. **Dir	ectorate Genera	al of Commerci	al Intelligence a

#### TABLE 1.

The ICT hardware market is expanding due to the new fields of ML, AI, and IOT. India has the capability to design specialized Semiconductors, Sensors, and Servers for these domains. Large-scale data centers are another emerging area in ICT hardware. India can lead the globe in all of these sectors because to its technological expertise, inexpensive labor, big labor pool, and English as its working language [4].

Look at the case study on the IOT enabled superefficient fans. Approximately 40 million ceiling fans are sold in India each year, of which fewer than three percent are SE models. INR 12,000 crore (USD 1.64 billion) is the potential market for SE fans annually. According to estimates, SE fans could reach a total market value of USD 20 billion (or INR 1,42,800 crore) in India's residential sector by 2020. There are already 410 million ceiling fans in households and an unmet demand of 66 million [5-6].

India is home to most of the world's largest fabless chip companies. In spite of this, India has yet to create any indigenous design IP. In order to manufacture high-quality semiconductor chips in India, highly skilled personnel are required. Manufacturing semiconductors requires skills in fields such as microelectronics, optics, physics, materials sciences, and chemistry.





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It can be rightly said that India has the capabilities to be a part of the IP creation supply chain for virtually all of the world's biggest fabless chip companies. Over the years, many major global semiconductor companies have established their chip development R&D centers in India [7].

#### II. LITERATURE REVIEW

Chris Miller, 2022 Chip War: The Fight for the World's Most Critical Technology The Chip War book discusses the strategic importance of semiconductor chip manufacturing ecosystems for each country, its importance in defense, self-sustenance, etc. Miller traces the history of the global semiconductor industry in his book. A large portion of the demand for semiconductors came from the U.S. defense and military establishment in the early days. Currently, that defense establishment relies on the chip industry for critical strategic and battlefield capabilities. Fred Warshofsky(1989) Chip War: The Battle for the World of Tomorrow The story starts with the early development in the US, focusing on Silicon Valley's rise and fall. In the following chapters, discussed the growing industry in Japan and the emerging developments in Taiwan and Korea, and we conclude with an assessment of the state of the industry in Europe.

Shakti.org (2014): Open Source Processor Development Ecosystem The Shakti microprocessor family, developed by IIT Madras under the Make in India initiative, was launched in 2014 to create indigenous microprocessors for defense, aerospace, and consumer electronics. Built on the RISC-V open-source ISA, these processors are energy-efficient, high-performance, and scalable, eliminating licensing fees. MeitY (2022): Ministry of Electronics and Information Technology MeitY (Ministry of Electronics and Information Technology) plays a crucial role in shaping India's digital and electronics landscape through a multi-pronged approach. Its goals encompass advancing eGovernment, facilitating sustainable development in the electronics and IT sectors, augmenting India's influence in internet governance, and safeguarding cybersecurity. It also supports semiconductor chip manufacturing by establishing policies, guidelines, and incentive schemes.

IEEE-ICEE (2022): International Conferences on Emerging Technologies ICEE Focus is on International conference on emerging electronics, Research Papers, Latest trends in Industry, Latest Innovation/RD&E. IESA (2023): India Electronics and Semiconductor Association IESA represents the ESDM & Intelligent Electronics industry in India and promotes technology solutions to positively impact the lives of 1.3 Billion Indians. IESA aims to make India the preferred ESDM destination through its close relationship with its member companies.

Kamakoti Veezhinathan, (2022) India's electronic systems rely heavily on imported microprocessors and microcontrollers, with designs protected by patents and strict licensing terms. The SHAKTI Processor Program, launched in 2014 at IIT Madras under the PC-CDISHA-RISE group, aims to address these limitations by developing open-source. Himanshu Kushwah, Anil Sethi(2015) India's electronics demand is set to grow, but manufacturing remains weak, with chip design companies relying on foreign FABs. Despite India's strength in EDA and IT services, its chip design sector is disconnected from local electronics manufacturing, limiting job opportunities.

PRANAY KOTASTHANE, ARJUN GARGEYAS (2022) Despite having a sizable domestic semiconductor industry, India is still heavily reliant on imports because of its lack of adequate domestic production capabilities. Despite having a skilled workforce in engineering and chip design, the country lacks robust semiconductor fabrication capabilities. Satyajit Bora, Roy Paily (2021) Modern IoT devices, smartphones, medical equipment, and communication systems require high-performance, low-power processors, especially for battery-powered applications.

Madhukar Patil, M. Suresh (2019) India's demand for electronic devices is rising in both domestic and global markets. While major semiconductor MNCs have design houses in India, manufacturing still largely occurs in China, Taiwan, and Malaysia. However, increasing costs in China are making India a viable alternative. Indian design centers support chip design and validation for global products, and the government's Make in India initiative is encouraging local investment. Mamidala Jagadesh Kumar (2021): Will India become a major hub for the production of semiconductor chips? Global semiconductor manufacturing is led by IDMs like Samsung and pure-play foundries like TSMC, while fabless companies such as Qualcomm and Nvidia drive innovation. The COVID-19 pandemic highlighted vaccine nationalism, and similar concerns over chip nationalism may affect India. Some nations stockpiled semiconductors, disrupting supply chains. In response, the Indian government has taken steps to boost domestic semiconductor





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manufacturing, aiming for self-sufficiency. John Chen, Emily Walz, Brian Lafferty, Joe McReynolds, Kieran Green, Jonathan Ray, and James Mulvenon (2018): China's Internet of Things China's growing role in international standards committees allows it to shape global IoT regulations. Increased Chinese research into IoT security vulnerabilities signals its strong national security interest in both protecting and exploiting these weaknesses.

Industry Session – I(2022) in IEE 2022 discussed, How India Can Deliver Its Own Intellectual Property to Become a Global Leader in Semiconductors Value Differentiation in Several Aspects of This Sector I've learned more about the semiconductor industry's widespread presence and its crazily deflationary character thanks to this session. IEE 2022's Industry Session III (2022) covered the topic of whether India is ready to produce semiconductors in large quantities. Even though India has made great strides in a number of high-tech areas in recent decades, the country still faces challenges in producing semiconductors. Is there a reason behind that? The stages necessary in constructing a production fab, important government regulations, and completion dates were all addressed in IEE 2022's Setting Up Large Scale Facs (2023) course.

The Human resources (2023) panel at COSEIn (2023) covered topics such as the total anticipated workforce required to operate atypical fabrication, different verticals that require skilled labor and their future, and skill development through certification, certificates, and degree programs, among other things. The COSEIn (2023) panel on Supply Chain and Consumables (2023) covered topics such as identifying different commodities and their volumes needed to operate a factory, modern machinery, maintenance and operations, the quality, quantity, and grade of various consumables, the current eco system, and adapting to new demands, among other topics. The panel on Existing Facilities & Pilot Plants (2023) at COSEIn (2023) covered topics such as the function of existing facilities, the significance of pilot production facilities, multiuser fabrication & characterization facilities in academic settings, the function of existing facilities in connecting production fabs and advanced R&D activities, etc [7-15].

#### III. RESEARCH METHODOLOGY

The phenomenon being studied in this research is to identify the factors influencing the development of the Semiconductor Chips Manufacturing Industry in India. Variables (Figure-2) for these studies include semiconductor chip design, semiconductor chip manufacturing, marketing needed to promote indigenously developed semiconductor chips, and government policies that facilitate the semiconductor eco system in India.



#### Fig 2. Variables used.

Qualitative research involves collecting and analyzing written words and text. A grounded theory approach (Figure-3) supported by quantitative data was used in this study. A theory explaining why something happened is constructed using qualitative data. An explanation is derived by comparing data from similar cases in different settings.





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Fig 3. Research Methodology Flowchart

Research was conducted with customers, end users, producers, suppliers, government representatives, industry experts, and these interviews provided insight into influencing factors, limitations in India, policies that drive, geopolitical situations, what is happening within India and around the world.



Fig 4. Data Collection Process

Research questions focused on

- Design: talent availability, ability to evolve across generations and improve etc
- **Manufacturing:** Build to print eco systems in India, scale requirements, resource availability
- **Go2Market:** how to ensure adoption, cost advantage vs current options and security of supply as the pitch
- **Policy Support:** R&D subsidy, capex subsidy for manufacturing, import ban on low-end processors, make-in-India vendor preference in Government tenders etc.

#### Hypothesis

#### Hypothesis (a)

Ha0: India ecosystem favorable in Development of Semiconductor Chips Manufacturing Industry Ha1: India ecosystem not favorable in Development of Semiconductor Chips Manufacturing Industry

#### Hypothesis (b)

Hb0: Identified Factors does Favor Development of Semiconductor Chips Manufacturing Industry Hb1: Identified Factors does not Favor Development of Semiconductor Chips Manufacturing Industry

#### Hypothesis (c)

Hc0: Strategies are Favoring Development of Semiconductor Chips Manufacturing Industry Hc1: Strategies are not Favoring Development of Semiconductor Chips Manufacturing Industry

#### Hypothesis (d)

Hd0: Policies are favoring Development of Semiconductor Chips Manufacturing Industry Hd1: Policies are not favoring Development of Semiconductor Chips Manufacturing Industry





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#### Hypothesis (e)

He0: Supply Chain India is favoring Development of Semiconductor Chips Manufacturing Industry He1: Supply Chain India is not favoring Development of Semiconductor Chips Manufacturing Industry

#### Hypothesis (f)

Hf0: Market favor acceptance of Indigenous developed Development of Semiconductor Chips Hf1: Market does not favor acceptance of Indigenous developed Development of Semiconductor Chips

#### **III. RESULT & FINDINGS**

#### TABLE 2. APPROACH FOLLOWED IN COLLECTING DATA.

Table-2				
Interviews	Survey	Focus Group	Observations	Documents & Records
Interviews	Online	IEEE Conferences	Investors Observation	Google Scholar
Discussions	In-Person	IESA Conferences	Geopolitical Situations	Business Magazines
Industry Expert		CoSE Conferences		MeITY Notifications
				Geographical change/Natural Disaster
				Govt Policy/Strategic Change

#### TABLE 3. PERCEIVED APPLICATIONS FOR INDIGENOUS MICROPROCESSORS (N=108)

Application	High Potential (Count)	High Potential (%)	Low Potential (Count)	Low Potential (%)	Moderate Potential (Count)	Moderate Potential (%)	Average Score (0=High, 3=Low)
Computers	69	63.9	10	9.3	29	26.9	1.4537
Servers	55	50.9	14	13.0	39	36.1	1.6204
Healthcare	61	56.5	5	4.6	42	38.9	1.4815
Defence	87	80.6	7	6.5	14	13.0	1.2593
loT	84	77.8	4	3.7	20	18.5	1.2593
AI	75	69.4	11	10.2	22	20.4	1.4074
Automotives	63	58.3	6	5.6	39	36.1	1.4722
Others	33	30.6	11	10.2	64	59.3	1.7953

#### TABLE 4. DEVELOPMENT PRIORITIES FOR MICROPROCESSOR DEVELOPMENT (N=108)

Factor	High Priority (Count)	High Priority (%)	Low Priority (Count)	Low Priority (%)	Moderate Priority (Count)	Moderate Priority(%)	Average Score (0=High, 3=Low)
Performance	95	88.0	1	0.9	12	11.1	1.1296
Cost	46	42.6	28	25.9	34	31.5	1.8333
Open-source Compatibility	68	63.0	3	2.8	37	34.3	1.3981
Reliability	102	94.4	6	5.6	0	0.0	1.0556
Branding	33	30.6	12	11.1	63	58.3	1.8056
Others	24	22.2	25	23.1	59	54.6	2.0093

#### TABLE-5: ECOSYSTEM READINESS ASSESSMENT OF INDIA (N=108)

Capability	High (Count)	High (%)	Low (Count)	Low (%)	Moderate (Count)	Moderate (%)	Average Score (0=High, 3=Low)
Design Capability	57	52.8	13	12.0	38	35.2	1.5926
Manufacturing Capability	18	16.7	43	39.8	47	43.5	2.2315
Talent Availability	55	50.9	12	11.1	41	38.0	1.6019
Academic / Research Capabilities	42	38.9	17	15.7	49	45.4	1.7685
Marketing	17	15.7	30	27.8	61	56.5	2.1204
Govt Policies	20	18.5	29	26.9	59	54.6	2.0633

TABLE-6: AWARENESS OF INDIA'S INDIGENOUS OPEN-SOURCE PROCESSOR (N=108)

Response	Frequency	Percent		
No	35	32.4		
Yes	72	66.7		
Missing	1	0.9		





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Government officials promised Rs 2.3 trillion in incentives in December 2021 as part of an India Semiconductor Mission under the current, broader PLI scheme. The electronics industry places a great deal of emphasis on semiconductors, also called chips. McKinsey estimates that the semiconductor market will grow by 6-8 percent per year for the next decade, despite an increase of 20% in 2020-21. A third of the federal government's commitment will be allocated over the next six years, and the allure of such incentives is attracting new proposals.

In any case, increasing India's chip design and manufacturing capabilities are rarely mutually exclusive. In many cases, they are even complementary. Prior to a few years ago, most chip design and manufacturing was done within vertically integrated businesses. Synergies can be created even without integration between design and manufacturing.

Manufacturing chips can be combined with other manufacturing processes, such as assembly, to produce a growing number of semiconductor-based products, including advanced microprocessors and basic recollection chips. Additionally, India is large enough to develop its own internal industrial networks, as well as regional and international ones.

Table-7 shows, the ecosystem is favorable for developing indigenous microprocessors and semiconductor chip manufacturing, however it needs streamlined effort to make it success. There is ecosystem exists for R&D, Design and small-scale manufacturing, however missing commercial level manufacturing. It is good to start with low end applications like IOT.

Qualitative data from open-ended Q1, Q23, Q24, Q25, Q29, Q30, Q31, Q32, Q33, and Q34 questionnaires were coded intensively with open, axial, and selective coding grounded theory analysis. Grounded theory analysis identified six major themes with several categories under each, which, collectively, define the setting of indigenous microprocessor research and development in India. Table-7 shows these six themes and discusses them in detail below.

# TABLE-7: CORE CATEGORIES AND EMERGING THEMES IN INDIGENOUS MICROPROCESSOR DEVELOPMENT

11000	Menninger	Examplan Quote			
1. Strategic Imperative and National Vision	The broader motivations and greater national goals driving the native microprocessor initiative, with a demand for technological independence, national security, and economic sovereignty.	India's more towards creating an indigenous open-source microprocessor is similar to a heroic and motivational step towards technological independence. It indicates that India is prepared to selae the future in the semiconductors' world, which is crucial for maintin security andinational development.			
2. Ecosystem Strongths and Gaps	The observed strengths and weaknesses of India's current semiconductor ecceystem, with design strength pitted against menufacturing weakness and lack of specialized talent.	Manufacturing capability was rated very low by starkly (39.8% low), reflecting India's dependence on overseas fabrication facilities.			
3. Policy and Governance Frameworks	The vision for the Government of India's initiative, the effectiveness of current policies, and recommendations for future policy initiatives to promote indigenous microprocessor development and utilization.	"Government of India has to play a key role in premoting R&D, developing supportive policies, promoting public sector uptake, establishing semiconductor infrastructure, driving skill building, and promoting collaborations." "Quick streamtined policies and ease of implementation."			
3. Market Acceptance and Promotion Strategies	The applications individuals perceive for indigenous micropocessors and the vertices means stakeholders feel are required to actually install and capture their marketplace acceptance.	Thespectations overhelseningly picked deficies (80.64) high potential) and IoT (77.89) high) as the most promising areas? Healt via asatemic collaborations, developer community unteractive, government uptake, industry partorships, unteractive, government, and associated communications, eper- sence introduces and aseminars, and associas to evaluate the associate introduces of correct accesses.			
3. Supply Chain Resilience and Localization	Techniques for constructing a strong and localized supply chain for indigenous microprocessors, resolving manufacturing and component availability problems.	"Offer local manufacturing support, establish strong vendor networks, lock up raw materials, invest in packaging/test facilities, establish strategic allances, offer government incentives, and build logistics for assumed distribution and scalability," "Americacing first projecty".			
6. Critical Challenges and Barriers	Significant obstacles and constraints that the stakeholders see as preventing indigenous microprocessor development and extensive use, including infrastructural deficits, shortage of	"Key problems are limited fabrication facilities, talent gaps, excessive R&D costs, foreign competition, dependencies in supply chains."			

All semiconductor efforts must be coordinated into one consortium, which requires significant effort. ISM is making great effort. The development of domestic semiconductor industries and the improvement of the global semiconductor ecosystem are integrally tied together through trade and technology transfers. Taiwan and Japan, which are giants of the industry, achieved their stature through more liberalized and open market policies.

Figure-5 briefs India's previous attempts and current plans at semiconductor fabrication and manufacturing since 1960's. Data clearly shows bureaucracy and Govt policies play major role. Technology transfer and trained employees is another important criterion.





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Fig 5.

#### **IV. CONCLUSION**

- Government assistance is essential for infrastructure, foreign technology, and financing.
- Focus on Cost & Performance.
- Import ban on low-end processors, make-in-India vendor preference in Government tenders to ease acceptance.
- Need to create a strategy to align chip designers, SCL, Govt & Production centre to create a clear roadmap
- India has capability in R&D, Design, Assembly & there is end market, however India lack manufacturing capability. Tata is putting to enable manufacture.
- Production businesses must go through a number of distinct design and production phases and procedures in order to develop a semiconductor chip. Any slowness or fault might offer rivals an advantage.
- The establishment of a fabrication manufacturing facility requires several billions of dollars.
- A single chip needs hundreds of liters of clean water, which our geography may make hard to obtain in adequate quantities.
- Sand is the first step in the technological wizardry required to create a semiconductor chip.
- Supply chain strategy depends on infrastructure, which must include production and quality control as well as transportation, capacity planning, and manufacturing outsourcing.
- In semiconductor manufacturing, water is consumed for a variety of reasons, including cooling equipment and cleaning wafer surfaces.
- Long-term policy development must address all the crucial characteristics. A global level of collaboration should also be achieved through trade and foreign policy to ensure access to foreign technology suppliers.
- Indian IP design has suffered from a lack of technology transfer agreements with more experienced manufacturers.
- Thanks to key government initiatives from MeiTY like the PLI scheme and the National Policy on Electronics, India's electronics manufacturing has grown rapidly. Production jumped from ₹1.90 lakh crore (USD 30 billion) in 2014-15 to ₹9.52 lakh crore (USD 115 billion) in 2023-24—a fivefold increase with annual growth over 17%.
- In addition to talent availability, rising demand is another key factor that contributes to semiconductor industry growth. The Indian semiconductor association estimates that the semiconductor industry will grow by ~29.4% from 2015 to 2025.
- India lacks full-fledged semiconductor supply chain ecosystem, there is effort needed to develop supply chain for semiconductor chips manufacturing.
- India lacks trained employees for semiconductor chip manufacturing.
- Industry and Academia collaboration is needed to develop technology and talent.
- In India, the ecosystem is favorable for developing indigenous semiconductor chip manufacturing, but it requires significant coordination among all the different initiatives.





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#### V. RESEARCH LIMITATIONS

- Research does not focus on the international market.
- Research does not define the technical specifications of semiconductor chips.
- Research does not focus on implementation of Govt policy.
- Research does not focus on implementation of supply chain strategy.

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