Leapfrogging of Goa to Electronics and Computing Leadership with DNA Computing

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There has never been an independent study of how Goa could evolve into an electronic powerhouse, other than reports published by the Government. This paper is an attempt to bring together perspectives of the Goa Chamber of Commerce and Industry, Private Electronic sector and Goan businesses on the challenges Goa faces and what could be the possible solutions to help Goa leapfrog in electronics and become an electronic/computing powerhouse. The research methodology is via systematic literature survey, focused group discussions to create a tension plot of the challenges that electronic sector faces in Goa. The solution arises out of the likely advantages that Goa has and how these advantages can be stitched together to weave a tapestry of a vibrant electronic and computational hub.

Keywords: DNA Computing, Leapfrogging, Electronic Leadership.

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1. Introduction

Goa state has a strong presence in Tourism, Pharmaceuticals and Fisheries. Before the liberation, Goa's economy was mainly based on agriculture and to a large extent on the mining industry. The state had a large population with knowledge of foreign language, a fairly high GDP and post-independence, the state was faced with the challenge of determining its own future. The rise of industries had to stem from the businesses which were in existence at the time and started off with the development of civil infrastructure like roads, irrigation projects, water supply and electrification. The labour force for the same was imported from other states and engineering colleges and polytechnics were established for developing the human resource in Goa. Electronics and telecommunication received a major push in the late 1990s and early 2000s, when the telephone and cellular communications infrastructure was established. The engineering colleges and polytechnics followed suit and established the faculties. Occupations started diversifying in the state and businesses to assemble TVs, telephones, cell phones, radios, etc...flourished and students passing from the ITIs and polytechnics started working in them. The electronics industry globally in the meanwhile transformed massively due to expansion of VLSI, ITC and the world entered into the 4th industrial revolution. This transformation affected the industry in Goa because radios, cell phones made way for ITC based components and paraphernalia. Industries which could adapt like those manufacturing internet routers, optical fibres, etc.. thrived but others were decimated. This paper is an attempt to study and assess the limitations, challenges and adaptations needed by the industry and educational institutes to establish Goa as a vibrant electronics and communications hub.

Inability to adapt to the 4th industrial revolution, has seen a decline of Goan electronics industries have seen a decline from 2016 to 2019, with around 2160.4 billion rupees lost due to loss of jobs and investments. [1] This is the inspiration to investigate the reasons for lack of resilience and adaptability of the Goan electronics landscape to the global changes.

2. Research Methodology

To arrive at the causes and the probable solutions, the research methodology followed was by – literature survey, interviews with key thought leaders followed by conclusions drawn from focused discussions.

2.1 Literature Survey

The current profile of Goa has certain strong points to attract electronics industry – it is well connected by all modes of transport, has a high GDP, fair ITC connectivity and seven engineering colleges, 5 polytechnics and several Industrial Training Institutes to provide the required manpower to the industry. However, the investment and footprint of the electronics sector remains fairly small forcing students to look for employment outside the state. The current IBEF survey gives a detailed profile on the current status of Goa. [1]

The literature on the current electronics status in Goa is fairly limited and is mainly restricted to the government's reports on electronics. [2] The government IT investment policy 2015 -2020, economic survey 2020 and the electronics manufacturing policy are the only documents allowing investors to gain a glimpse into the state's attractiveness for electronics investments. [3]

Considering the end-to-end chain of launching an electronic product in the global market has the following steps:

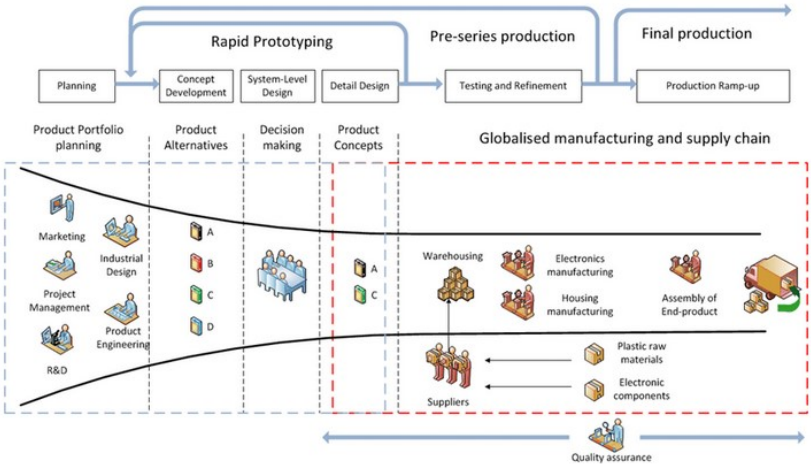

Fig.1 End to end Stages of launching an electronic product

The comprehensive process of launching an electronic product in the global market involves a series of interconnected stages, as illustrated in Fig. 1: End-to-End Stages of Launching an Electronic Product. To excel in this endeavour, a state must navigate through a spectrum of activities encompassing product planning, meticulous design, rapid prototyping, seamless conversion of prototypes into manufacturing-ready products, strategic launch initiatives, and effective distribution channels. Crucially, this entire chain must exhibit agility and responsiveness to the dynamic shifts in customer preferences.
For a state to excel at launching electronics products – the entire repertoire of activities from product planning, product design, rapid prototyping, converting prototypes to manufacture ready products, launching and distribution are needed. The entire chain must be agile and responsive to rapidly changing customer needs. Designing and rapid prototyping skills are most evolved close to large semiconductor fabs in China / Taiwan and North America. [4]

Highly developed design and rapid prototyping capabilities are notably concentrated in close proximity to major semiconductor fabs in regions such as China, Taiwan, and North America [4]. Recognizing this landscape, India, and specifically Goa, should formulate and implement electronic policies that align with the evolving global supply chains in electronics. Given its standing as a relatively low-cost manufacturing hub, India is positioned to attract investors, with a focus on assembling products in high demand, such as smartphones and internet routers. Additionally, leveraging existing ancillary units, including battery, charger, and connector manufacturers, contributes to a holistic electronic manufacturing ecosystem.

In the context of the ongoing fourth industrial revolution, often referred to as Industry 4.0, the world is witnessing a rapid transformation characterized by the pervasive integration of smart connected devices. This revolution underscores the demand for products capable of automating mundane and repetitive tasks, liberating humanity from manual chores. The shift towards internet-enabled services and platforms presents an opportunity to replace repetitive services requiring unskilled labor with innovative, technology-driven solutions [5]. As such, a strategic approach to electronic product development and manufacturing is essential to align with the current trajectory of global technological advancements.

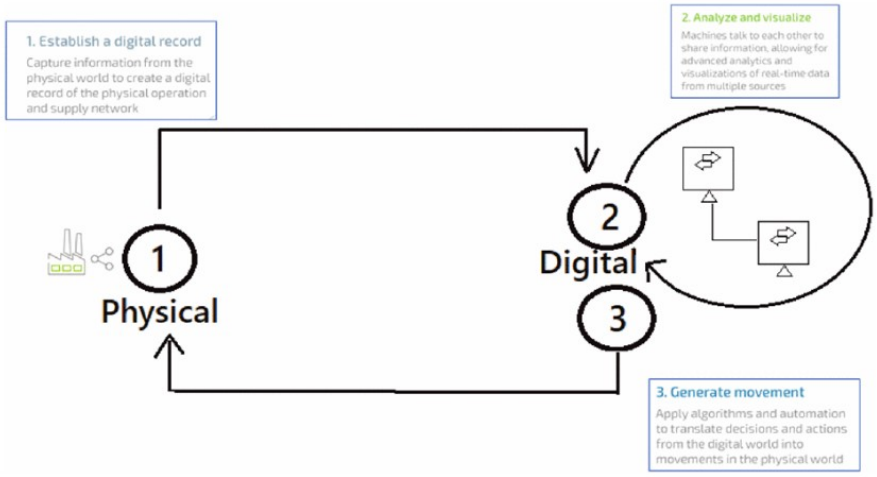

Fig.2. Framework of Industry 4.0 [5]

Fig. 2 illustrates the Framework of Industry 4.0 [5], where any physical object can be digitized through an IoT sensor connected to the internet. This connectivity facilitates control, information communication, decision-making, and the generation of data-driven actions. The integration of Internet of Things (IoT)-enabled devices has revolutionized remote monitoring in healthcare, offering the potential to ensure patient safety and well-being. This transformative technology empowers physicians to deliver exceptional care, enhances patient engagement and satisfaction through streamlined interactions, and contributes to the reduction of hospital stays and prevention of re-admissions. The widespread adoption of IoT not only significantly cuts healthcare costs but also improves overall treatment outcomes.

The aftermath of the recent pandemic has accelerated the adoption of smart solutions in various sectors, including smart cities, smart manufacturing, and smart educational institutions. The shift in work dynamics has made smart technologies indispensable for optimizing workspaces and delivery systems.

However, the current state of Panaji, aspiring to be a smart city, does not align seamlessly with the ongoing Industry 4.0 transformation [6]. While foundational components are in place, such as basic energy efficiency measures and electronic surveillance using CCTV cameras for crime reduction, there's substantial room for improvement. A more comprehensive vision document is needed, incorporating specific components of Artificial Intelligence, Decision Support systems, and automation. Addressing these aspects is crucial for a city to truly embrace the Industry 4.0 paradigm.

This transformation is not just about technology; it represents a grander, more inclusive vision. Moving towards this vision with courage and determination is essential. A well-implemented smart city project not only enhances the quality of life but also generates employment opportunities, particularly in high-

end sectors. This, in turn, benefits the local graduate and postgraduate electronics workforce, ensuring their gainful employment and contributing to the city's overall development.

3. Focused Discussions with Key Opinion Leaders in the Electronics Industry in Goa

The below account are the distilled thoughts of several key opinion leaders in Goa from the GCCI to the managing directors of electronics industry in Goa:
The causes which prevent Goa from changing into an industrial hub are:

3.1 Rapid Customer Value Chain Compression

Enterprises are looking at innovative models that eliminate the middlemen and leverage digital platforms to reach the end customer. Retailers are adopting direct-to-consumer models that displace the need for physical stores. Value chain compression has also set with miniaturization of electronic components.Many of the age old electronic devise has become obsolete. Manufacturing and assembling electronics industries for these products had to shut shop. The double whammy of industry 4.0, and rapid value chain compression necessitates a very responsive end to end, electronic idea to market journey.

3.2 Lack of Semiconductor Fabs for Self-Reliance

The challenge of lacking semiconductor fabrication facilities for self-reliance is a longstanding issue, necessitating a shift from heavy reliance on China and the US for crucial aspects of the electronics supply chain. It is imperative to design chips tailored for the domestic market and integrate them with local foundries. The on-going global chip shortage, affecting industries across sectors, underscores the urgency of establishing indigenous chip manufacturing facilities. This becomes crucial as electronic components find applications in diverse segments today.
Semiconductors have been pivotal in advancing electronics over the last 50 years, and their role will intensify with the emergence of new technologies such as the Internet of Things (IoT), artificial intelligence, 5G, smart cars, smart factories, data centres, and robotics. The complexity and research intensity of semiconductor manufacturing demand substantial and sustained investments.

To foster innovation and development in this realm, it is essential to extend support to IoT-based start-ups in India. This includes providing adequate infrastructure funding and creating a world-class environment conducive to research and development. Recognizing the significance of semiconductor manufacturing, the Government of India has introduced production-linked incentive (PLI) schemes to attract semiconductor fabs to establish their base in the country [7]. This initiative is aimed at creating a self-sustaining domestic model.

Moreover, industries in India, including those in Goa, can explore partnerships with established semiconductor fabs such as TSMC, Intel, Samsung, etc. This collaborative approach can contribute to a more robust and resilient electronics ecosystem, reducing dependence on external sources. Aligning with the central government's efforts, Goa should actively participate in enhancing the electronic footprint in the state. Fig. 3 illustrates the PLI scheme as a crucial tool to attract investments into India, signalling a commitment to bolstering the semiconductor manufacturing sector [7].

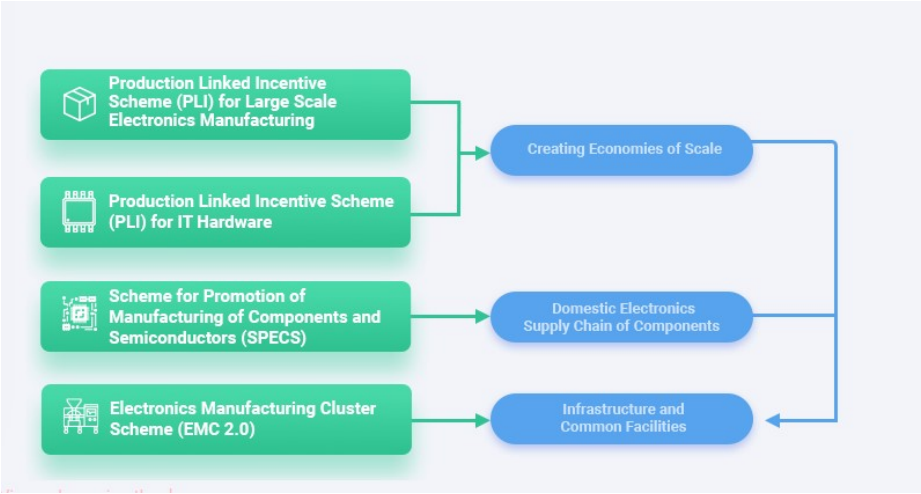

Fig. 3. PLI scheme to attract investments into India [7]

3.3 Public Private Partnership (PPP) Models in Goa for Electronics

The public sector and the private sector in Goa should join forces and implement several PPP projects. PPP models have succeeded in highway implementation and other civil engineering projects. The same can be extended to the electronics sector especially in designing smart cities.

The collaboration between the public sector and the private sector through Public-Private Partnership (PPP) models is envisioned as a transformative strategy for advancing the electronics sector in Goa. Much like the successful implementation of PPP models in highway development and other civil engineering projects, the same synergistic approach can be extended to the electronics domain, with a particular emphasis on the design and development of smart cities. The call for a partnership between the public and private sectors implies a shared commitment to progress and development. By pooling resources, expertise, and capabilities, both sectors can leverage their respective strengths to propel the electronics industry forward. Highlighting the success of PPP models in infrastructure projects, particularly in highway development, emphasizes the effectiveness of such collaborations. These models have proven instrumental in overcoming challenges and delivering projects efficiently.

Application to Electronics Sector: The extension of PPP models to the electronics sector signifies a broadened scope for collaboration. This includes initiatives related to the establishment of electronic manufacturing units, development of research and innovation hubs, and the implementation of smart city concepts. The included figure (Fig.4) likely provides a visual representation of the proposed PPP vision for a smart city in Goa. It may illustrate the integration of technology, infrastructure, and urban planning, showcasing the interconnected elements of a smart city.

Integration of intelligent systems for efficient energy use, waste management, and transportation, Incorporation of advanced technologies such as IoT, AI, and automation for improved city services and citizen experience, Enhancement of public services through digital platforms, ensuring responsiveness and accessibility, Representation of the collaborative framework between public and private entities to drive smart city initiatives are some of the potential points of Fig 4

In conclusion, the advocated PPP models serve as a visionary approach to propel Goa's electronics sector into the future, capitalizing on the strengths of both public and private entities to realize the development of smart cities and innovative electronic solutions. The success of such collaborations hinges on effective coordination, shared objectives, and a commitment to sustainable progress.

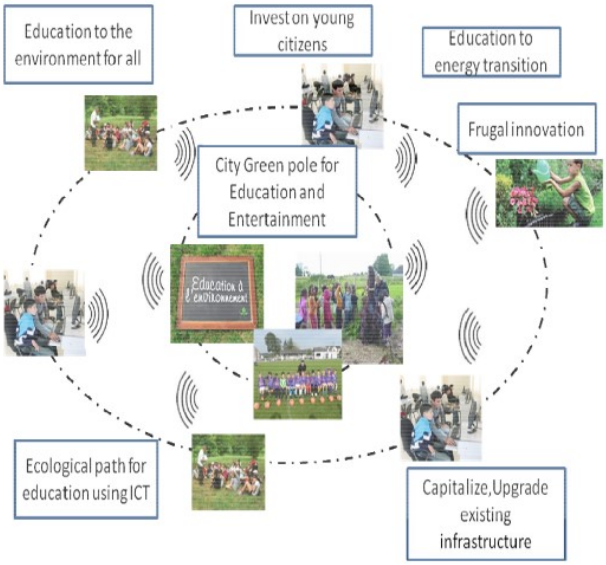

Fig.4. PPP vision for a smart city

3.4 Addressing Skill Gaps Based on the World Economic Forum – Jobs of the Future

Annually convening, the World Economic Forum (WEF) stands as a global authority shaping the strategies of industries and economies, addressing critical challenges such as wealth inequality, global warming, sustainability, and employment trends. It is paramount that educational institutions and industries in Goa align their vision with the job trends predicted by the WEF. In the era of Industry 4.0, certain jobs may become obsolete due to automation, but a myriad of new opportunities will emerge. Therefore, our educational systems must prepare students to meet the demands of these evolving job landscapes.

As reflected in the WEF report [8], key skills in data analytics, artificial intelligence, IoT, and machine learning are poised to be in high demand in the near future.

Fig. 5 illustrates the anticipated future job trends based on the WEF survey in 2018 [8]. This visual representation serves as a guide for stakeholders, signaling the skills and expertise that will be crucial for the workforce of tomorrow. By focusing on these areas, educational institutes and industries in Goa can proactively bridge skill gaps, ensuring that students are equipped with the knowledge necessary for the jobs that will shape the future.

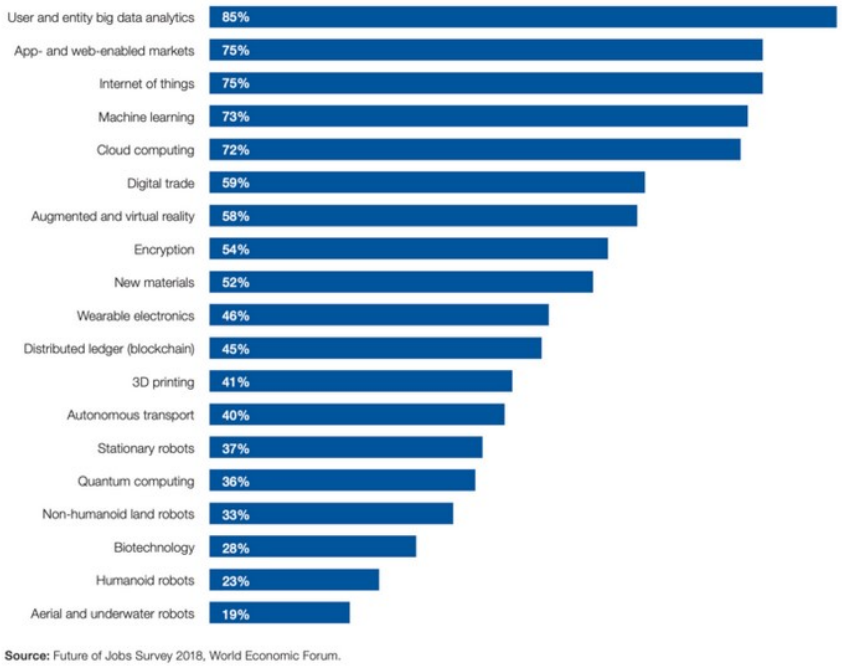

Fig.5. Future Job trends based on WEF survey, 2018 [8]

3.5 Lack of an Agile Response to Customer Needs

Addressing the Challenge of a Non-Agile Response to Customer Needs:
Constructing an agile organization for product development necessitates a combination of foresight and contemporary management principles. In this context, Goan industries, educational institutions, and supply chains must embrace agile and lean methodologies to enhance their overall work efficiency and responsiveness to customer needs.

Fig. 6 illustrates the Agile Methodology, a visual guide to the principles and practices that underpin agility in organizational processes. By adopting these methodologies, entities can create a nimble and adaptive environment that allows for swift responses to changing customer requirements.

The essence of agility lies in fostering a culture of continuous improvement, collaboration, and adaptability. By incorporating these principles into their workflows, Goan industries and educational institutes can not only meet the evolving needs of their customers but also position themselves as agile entities in a dynamic and competitive landscape. This adaptability is crucial for navigating the uncertainties and rapid changes that characterize today's business environment.

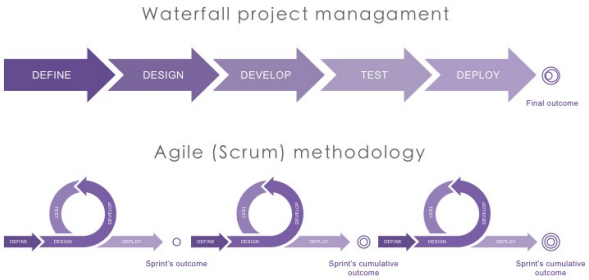

Fig.6. Agile Methodology

3.6 Fear of Return on Investment (ROI) Due to Uncertain Supply Chain and Delivery Challenges

Last couple of years due to COVID-19, shipping disruptions and erratic weather shook up the supply chain. A company can mitigate the chances of disruption to the flow of production and goods and address problems early on by matching their available resources and abilities with the opportunities and obstacles of unknowns that may occur. With a risk mitigation plan put into practice, companies can identify vulnerabilities, diversify suppliers and more. As a result, companies are able to track losses in sales and continue to preserve their reputations. This adoption of proper risk management grants the opportunity to maintain ROI, while also increasing visibility and providing enough time to react. The supply chain issues of electronic components have been an intractable problem for a long time -

3.7 Supply Chain Issues in Goa

Short supply chains are needed to reduce idea to market time and also reduce risk from damage to electronics components and finished products during transport.

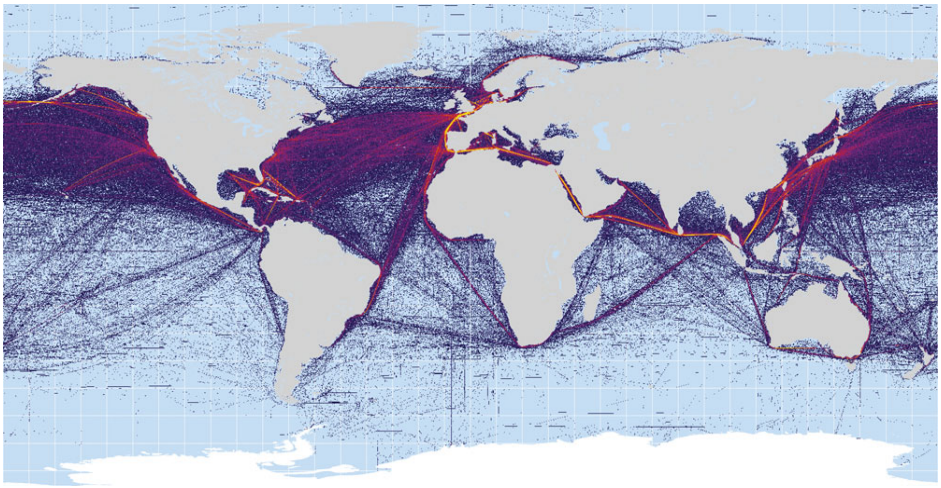

Fig.7. International Shipping Routes from China/Taiwan

Efficient and streamlined supply chains are imperative for reducing the time from idea to market and mitigating risks associated with potential damage to electronic components and finished products during transportation.

Fig. 7 illustrates the International Shipping Routes from China/Taiwan, showcasing the intricate network through which electronics components are transported. However, challenges arise as these routes may not be optimized for the most direct path to India, resulting in increased costs for raw electronics components.

The predominant customer bases for electronic goods are situated in North America and Western Europe, and Goa's geographical location poses challenges for the distribution of finished goods. The existing port in Goa primarily functions as a mining port, lacking the infrastructure to handle electronic cargo efficiently.

To address these supply chain issues, it is crucial for stakeholders in Goa to strategize and optimize supply chain routes, focusing on shorter supply chains to expedite the time from concept to market and reduce the vulnerability of products during transit. Additionally, exploring alternative distribution channels and ports that can accommodate electronic cargo will be essential for enhancing the overall efficiency and cost-effectiveness of the electronics supply chain in the region.

4. Preferred Solutions for Goa's Development in Electronics

In a strategic move to bolster electronic manufacturing, the Government of Goa has implemented a single-window approach for investors. The detailed steps for establishing electronic manufacturing units in Goa are elucidated in Figure 8. This systematic framework is designed to simplify the process, providing a cohesive and efficient pathway for investors to set up electronic industries in the region. The single-window approach reflects a commitment to fostering a conducive business environment, positioning Goa as an appealing destination for electronic manufacturing ventures.

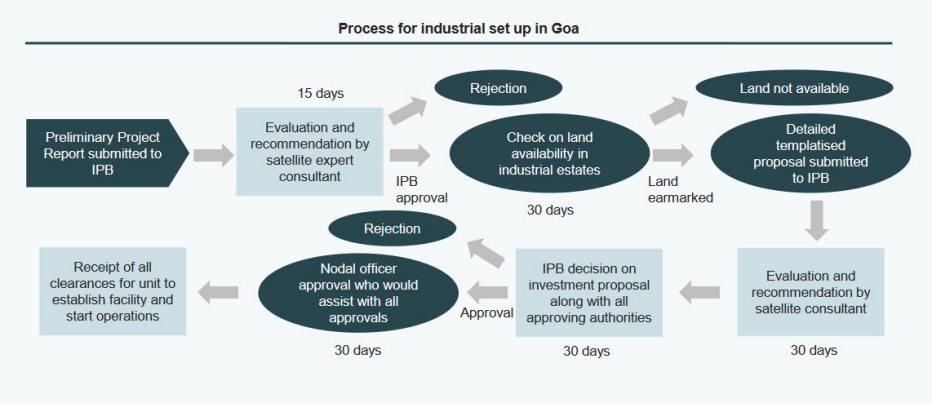

Fig. 8 Single window approach to set up an electronic industry in Goa

Cost of doing business in Goa

IBEF
INDIA BRAND EQUITY FOUNDATION
www.ibef.org

Cost parameter	Cost estimate
Industrial land (per sq ft)	US$ 10-50
Office space rentals (per sq ft per month)	US 60 cents to US$ 2
Residential rentals (for a 2,000 sq ft house per month)	US$ 800-1,300
Five-star hotel room (per night)	US$ 160-800
Power cost (per kWh)	Industrial: US 4.7-7.3 cents
Labour cost (minimum wage per day)	US$ 3.9-5.5

Fig.9. Cost of doing business in Goa

Figure 9 sheds light on the cost advantages that make Goa an enticing investment destination.

The figure underscores Goa's competitive edge by illustrating that the overall cost of doing business in the state is notably lower than in most other locations across India. Within the figure, factors contributing to this cost-effectiveness, such as affordable infrastructure, well-connected transportation networks, and reasonably priced industrial spaces, are likely visualized. A key focus is on the labour market, showcasing that Goa provides a skilled workforce at a favourable cost, making it an attractive proposition for industries seeking efficiency without compromising quality. The figure highlights the business-friendly regulatory environment in Goa, emphasizing streamlined processes, ease of obtaining permits, and potentially, any government incentives fostering a supportive ecosystem for investors. In essence, Figure 9 encapsulates Goa's appeal to investors as a destination where the cost of doing business aligns with efficiency, affordability, and a conducive regulatory framework, making it an ideal choice for both domestic and international investments.

This visual representation serves as a succinct yet powerful testament to why Goa stands out as a cost-effective and investor-friendly business environment. In conclusion, Figure 9 likely underscores that the cost of doing business in Goa is lower compared to most locations in India. The state's favourable cost dynamics encompass a holistic view of infrastructure, real estate, labour, government support, taxation, cost of living, market accessibility, and risk management. This comprehensive evaluation makes Goa an attractive and cost-effective destination for potential investors and businesses seeking sustainable growth.

5. Conclusions

5.1 Models for Goa to Develop into an Electronic Hub

Goa has not been able to attract big investors like Wipro, Intel, Samsung, IBM and others to create a vibrant electronics hub. However, all is not lost. Research into the several aspects of Goa and after a detailed SWOT analysis [9], the suggestion is that Goa could follow a short term and a long term development model:

Short term model: establish conventional electronic manufacturing units especially attracting MSMEs to the state as there is a large domestic supply of human resource. This is necessary to satisfy the current needs of the state, invite investors and increase employment. However, this approach

cannot bring Goa to a state of leadership in electronics. It will always end up as a follower and dependent on external forces to shape its future. It is not an enviable position.

Long term strategy: We need to work on a long-term strategy by taking leadership in an area of computing that will set us on the path to leadership. Two domains on computation that seem to be promising are:

- Quantum Computing [10]
- DNA computing [11]

Understand India's and Goa's strength in microbiology / biotechnology / pharmacology and focus on taking a leadership in developing newer computing techniques like DNA computers. DNA strands can be used for designing logic gates. In future, this could change the nature of computing and solving complex problems NP Hard problems.

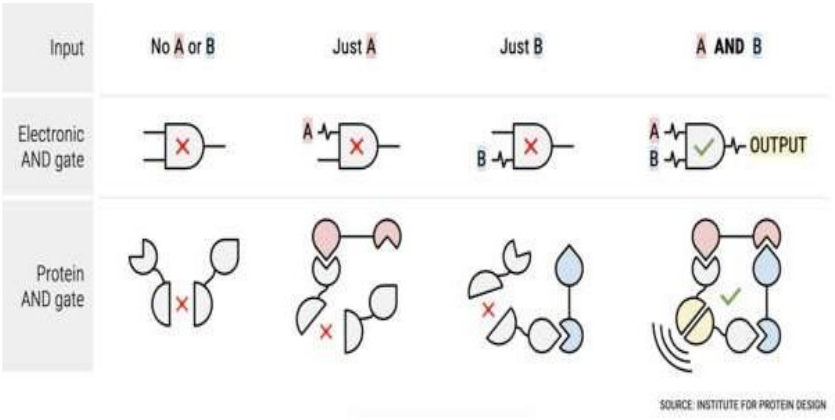

Fig. 10. DNA computing models

India's amazing journey of developing an indigenous vaccine for covid-19, in one year and home to the largest global vaccine manufacturer ….an amazing feat to be self-reliant.

It seems that Goa has all the right ingredients to invest in long term research into DNA computing. The DNA computers will not replace conventional computers. The DNA computers will work on data stored in public/private/hybrid clouds and be used to solve NP hard problems in finite time. This can be initiated by the public and private funding into PhD programs in DNA computing to generate the basic blueprints for DNA computing. The DNA computers should be incorporated into conventional cloud architectures, such that for NP hard problems. The cloud architecture has to be heterogenous and also economical for end users and this will hopefully set Goa on the path for leadership in electronics and computing.

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