



Frugal Engineering

by

Dr. P K Dan



Indian Institute of Technology Kharagpur

[Part – 1]



The context and Priorities: influencing Opportunity and Scope

- If we plan do anything – where do we do it?
 - Where lies the Scope?
 - Or, more precisely who do we target; and what is that market?
 - Where should we focus for Innovation or Entrepreneurial efforts?
and also very importantly as to, How?
- First, about the emerging market opportunity:

5.5 Billion people live in low-income countries or emerging economies in a world with a population of 8 Billion (1.4 bn in India alone).

This **market**, for **innovative products** or service **designed with frugal** or affordability **engineering**, is actually larger if we consider an immense opportunity through ‘Reverse Innovation’ process.

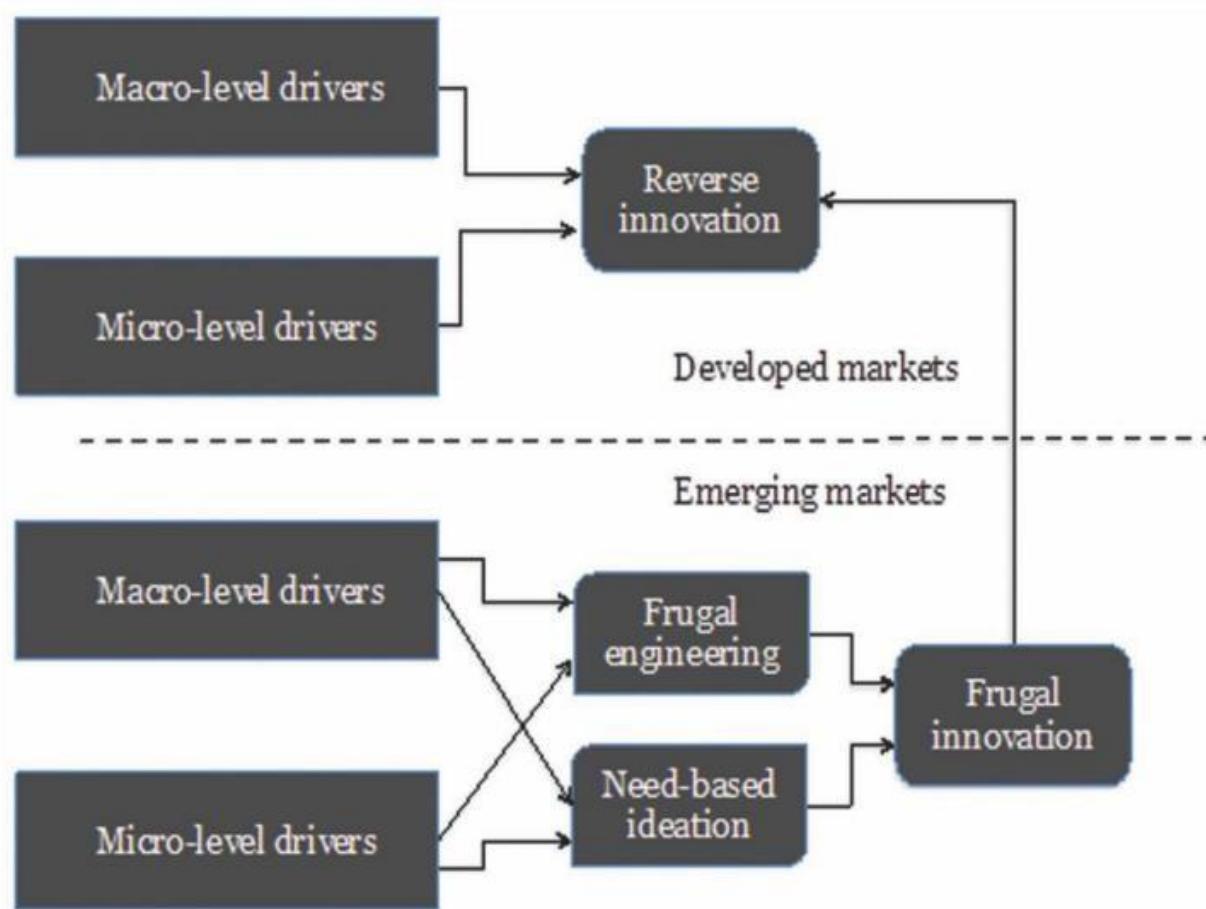
(‘Reverse Innovation’ will be discussed along with Frugal Engineering)



Reverse Innovation (RI) vs. Frugal Innovation (FI)

Source: Simula et al. (2015)

Need-based solutions and frugal engineering - two principal sources of frugal innovation and the fundamental building blocks in conceptual framework relating FI and RI. (Sometimes FI becomes RI)



https://www.google.com/search?q=entrepreneurship+includes+intrapreneurship&sxsrf=ALeKk02rIMR3bVGAd3ttm8iPlusRH2OClQ:1592985339144&tbo=isch&source=iu&ictx=1&fir=LLzjkcM%252CdyxxtSTGkfeqM%252C_&vet=1&usg=AI4_kTRZbXiTj-sDjhO10rwP9RbdI34A&sa=X&ved=2ahUKEwi2nZbq_JnqAhVsyzgGHWS0AxIQ9QEwC3oECAoQEg&biw=1366&bih=608#imgrc=lawsDg0FIPkhXM

INNOVATION AND LEADERSHIP (Vision and Resilience) IS THE COMMON ELEMENT

: SO WILL BE THE FOCUS and THE JOURNEY



Industry and Innovation

- “There is no other organizational capability with such a gap between importance and performance. In the 2015 BCG survey, 70% of executives replied that innovation was either the company’s top priority or among the top three.
- Other surveys by IESE, KPMG and The Conference Board confirm these numbers.
- Executives consider innovation as the most critical capability for the future success of their companies. But when asked about their satisfaction with the performance of innovation, less than 20% of the executives was happy based on a survey of our clients.”

—London School of Economics and Political Science, 2016

Firms are accelerating efforts to change their cultures, foster innovation, and serve customers more effectively.

Report on Innovation Strategy for Frugal Products

■ Over the past few years several media and Consultants' report indicate that the emerging markets are becoming dominant determinants in global business and is illustrated with following examples:

■ **ToI** reported some years ago, under a heading '**Reverse innovation: More MNCs take India's frugal engineering global**'

where one of the examples was of **Samsung**, a South Korean Global Company which is taking advantage of **frugal engineering** and lower development costs in India for developing products which are cost-effective and relevant for global market.

The other example was of **Renault**, the French car manufacturer, that developed a car conceived and build from scratch by its Indian R&D, as a part of **Frugal Engineering Strategy** championed by **Carlos Ghosn**, the CEO of Renault-Nissan Alliance.

LG, BSH (Bosch and Siemens) also undertook similar developments.

Report on Value sensitive (Cost & Quality) Emerging Market

- According to the Consulting firm, **PWC**, the **Global Emerging Middle** (GEM) is a class of consumers define a critical growth horizon for companies over the coming decade. Termed as the '**Next 4 Billion**' in countries like India, China, Indonesia, Africa and Latin America where over 4 billion people lived, only few years back when world population was 7 billion. If the **next lowest bracket is considered, it will cross 5 bn.** **A market of USD 6 Trillion, annually**
- Enterprises are challenged, in this market, to come up with **new value propositions** with new ways of thinking (**Quality and Affordability; Quality is fulcrum**). Innovations / products developed in these countries can be exported to Western countries (Reverse Innovation).
- Companies, according to the consultants, have to **collaborate with key players in the emerging economy** to supports their business model. While **prototyping and pilots are required in the initial stages, scale solutions are essential for success.**

Key Pointers from Reports for Planning Design and Innovation

- New Value Propositions
- Products with Quality and Affordability; Quality is fulcrum
- Frugal Innovation and Reverse Innovation
- Affordability Engineering or Frugal Engineering
- Defining Innovation for Identifying and Executing Projects
- Application of Technology in economic manner
- Gain economic leverage by serving large population and market

The **above, focused on product**, to be addressed through:

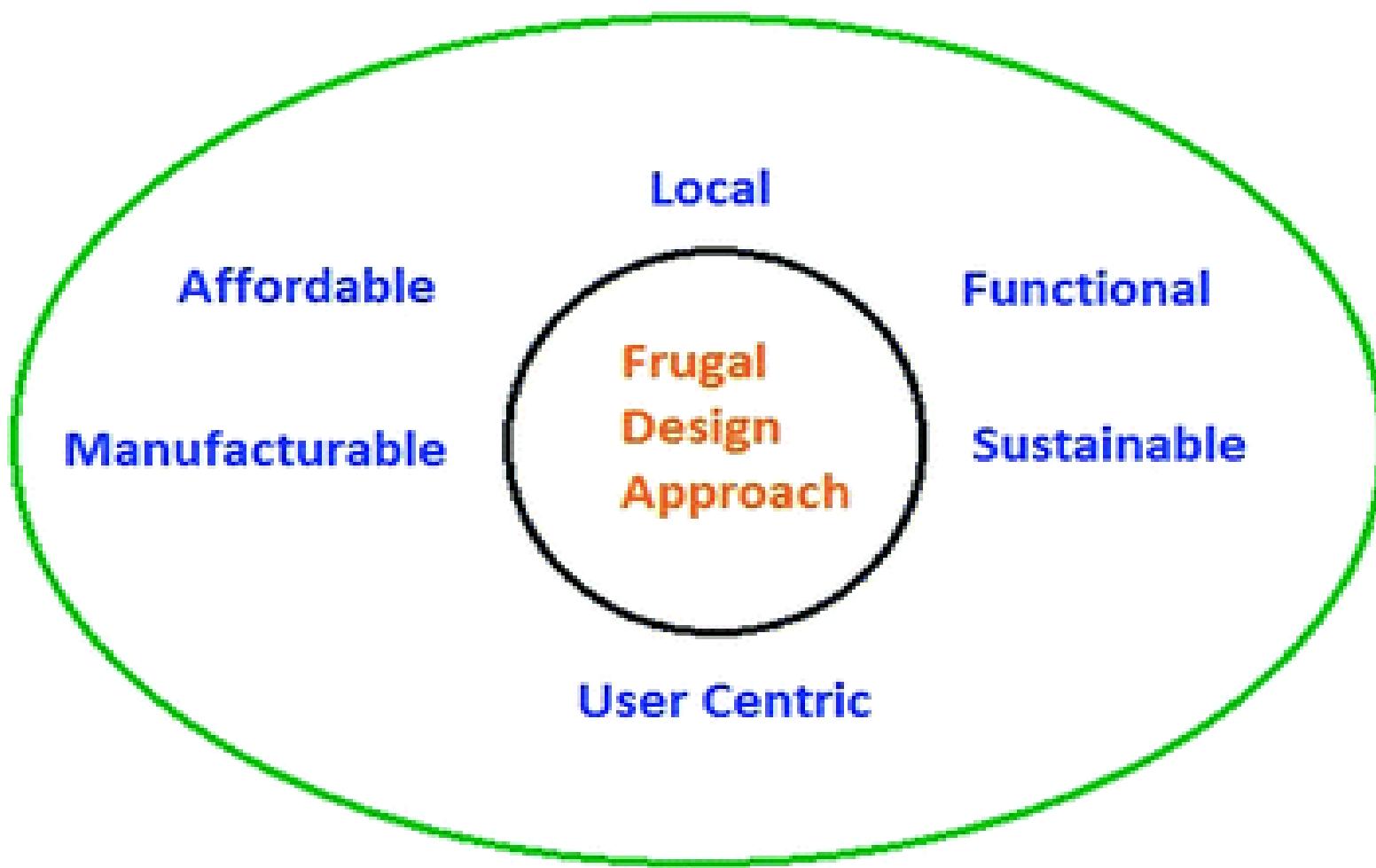
Frugal Design (FD) Thinking

Engineering Design and Innovation

Frugal Design Thinking:

Features integral to frugal design approach

https://link.springer.com/chapter/10.1007/978-981-10-0606-7_4



- **A definition of Innovation:** Executing an **idea** which **addresses a specific (real) challenge** and **achieves value** for both the **company and customer** (*summarised by N. Skillicorn*)

- **A definition of Frugal innovation in market:** New or significantly improved products (both goods and services), processes, or marketing and organizational methods that seek to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal) with the objective of significantly reducing the total cost of ownership and/or usage while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards (R. Tiwari and C. Herstatt).

Frugal innovation entails rationally minimizing resource usage, making things more affordable, and accessible - **all key goals of sustainability.**

- **for businesses,** this implies finding ways to create products, technologies, and processes **for improved sustainability.**

Frugal Engineering is Ubiquitous

- **Frugal Engineering practice and Frugal Innovation approach spreads across High Technology domain to conventional technology domain.**

It is applied in developing Space-Craft (MoM) as well as for small battery operated Refrigerator (Godrej, Chotukool).

From designing Cars – Nano (TATA), Kwid (Renault) or Logan (Mahindra Renault/ Verito (Mahindra) to designing infant incubator (Stanford)

From designing Electrocardiogram Machine or Ultrasonic Scanner (GE) and X-Ray machine (Siemens) to Prosthetic Limb (Jaipur Foot)

Therefore, it can be employed for and at any technology point in the entire engineering design space.

It combines technologies like artificial intelligence or IoT, together with standard and existing ones to create Frugal Products.

Frugal Engineering: Meaning and Principles

- The term '**Frugal Engineering**' was first coined in 2006 by Carlos Ghosn, the CEO of Renault, who ascribes it as the process of designing and developing the world's cheapest car targeting the base of the economic pyramid customers in India - **TATA Nano**.

Large western companies began to use Tata Motors' strategy
(Andrea Bencsik et al., 2016)

- Frugal Innovation is both a philosophy and outcome, while Frugal Engineering refers to the actual product development practices and the result of frugal engineering are frugal products.
- Frugal engineering, conceptually rooted in Appropriate Technology, is an approach to product development which scrutinizes the wastefulness of over-engineered products, and challenges the traditional business model for R&D of Western companies.

Frugal Engineering: Meaning and Principles (Contd.)

- Frugal engineering consists of a set of principles and methods used to design and develop low-cost, high-quality products in order to satisfy the needs of Base of the Pyramid (BOP) markets.
- Though cost cutting is a salient feature of frugal engineering, the consideration, rather, is for avoiding unnecessary costs while to ensure that the product is functional in resource constrained environments.



- Non-traditional Supply Chain is an important need.

We will see some examples

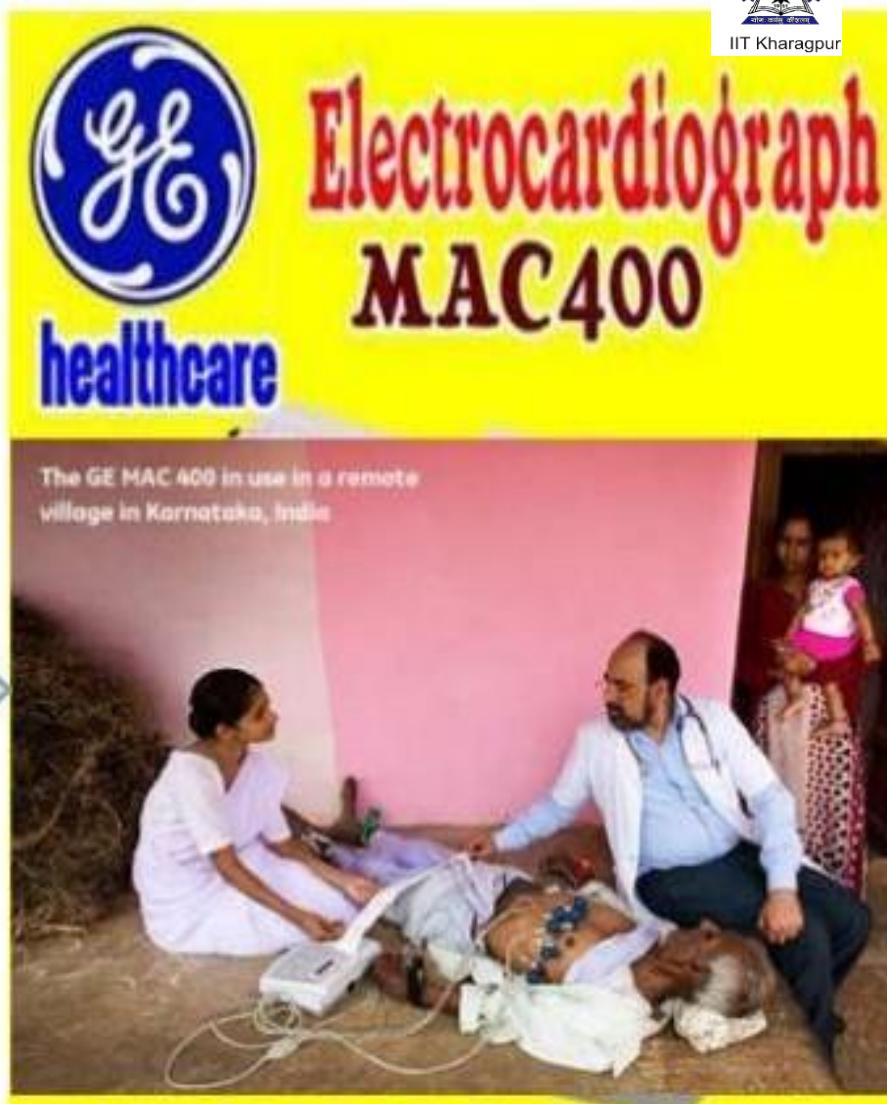
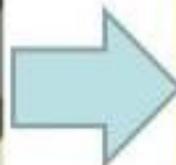
Innovative Frugally Engineered products: Examples

Such as, Medical Equipment, Agricultural Tractors, Automotives, Refrigerators etc with drastic cost reduction while preserving value

MAC 400 ECG Machine: **General Electric**, for instance, has developed several healthcare devices for rural markets in emerging economies and **electrocardiogram** is one such device. Normal cardiograms are very complex devices and only trained cardiologists are able to use them, while General Electric's frugal cardiogram removed all unnecessary components and reduced product and process complexity significantly by using substitute locally available materials, use **printers from local bus terminals** and off-the-self components.



\$10K vs \$1000



**Electrocardiograph
MAC400**

The GE MAC 400 in use in a remote village in Karnataka, India.

making ecg available
to every physician,
every patient, everywhere!

Traditional ECG



Frugal: MAC 400 ECG



MAC 400 ECG Machine

MAC 400 system developed by GE Healthcare, is a portable electrocardiogram (ECG) machine

designed to provide high-quality ECG data while being more frugal in terms of cost, size, and complexity compared to traditional ECG machines.

- **Low-Range:** Basic ECG machines: 50–100 watts.
- **Mid-Range:** Advanced ECG machines with features: 100–150 watts.
- **High-Range:** Premium ECG machines with advanced features: 150–200 watts.

Ultraportable device that weighs 1.3 kg (with battery)
– allows battery powered operation and features wireless connectivity.

Mac 400 costs Rs 35 -40 K, and after a single charge is capable of processing 100 ECGs.

The MAC 400 ECG system offers two distinct recording modes: automatic mode ECGs and manual mode recording.

Simple User Interface

Focused Functionality

Portability and Size

Cost Effective

Multiple ECG Modes

Uses GE's Marquette 12SL analysis program, features built-in software for interpretation (in English) of ECG and has integrated printer option.

One touch operation for acquisition, analysis and printing and focuses on acquiring high-quality ECG data efficiently.

Focused Functionality

- **Acquisition:** Users only need to press one button to start the ECG acquisition procedure just by attaching electrodes to the patient. The ECG waveform may be automatically detected and shown by the device.
- **Analysis:** The MAC 400 has fundamental analytic features that aid in spotting frequent ECG anomalies.
- **Printing:** Using yet another one-touch command, users can quickly print the outcomes after the ECG data is collected and evaluated.

Simple User Interface

- **Easy to Use:** The user interface is simple to understand, and requires little training.
- **Quick Setup:** The device's ease of setup and use lessen the amount of time needed to prepare the patient before beginning an ECG recording.
- **Immediate Reporting:** ECG reports can be printed right away using the built-in printer, enabling prompt delivery of results.
- **Time Savings:** Both medical personnel and patients can save time because of the quick setup, effective data processing, and immediate reporting.

Cost Effective

- Simplified design and reduced feature set of the MAC 400 system contribute to lower manufacturing costs.
- Traditional ECG equipment costs Rs. 1 lakh or more, depending on the specifications.

The MAC 400 , on the other hand , ranges in price from Rs. 35 to 40K

The price of an ECG test has been lowered to \$ 1 per person.

Portability and Size

- Unlike traditional ECG machines, the MAC 400 system is light-weight.
- Long-lasting Battery using Li-Ion tech, lasts for 100 ECGs in auto mode and recharges in less than 3 hours .
- MAC 400's portability extends its utility to remote or mobile medical setups .

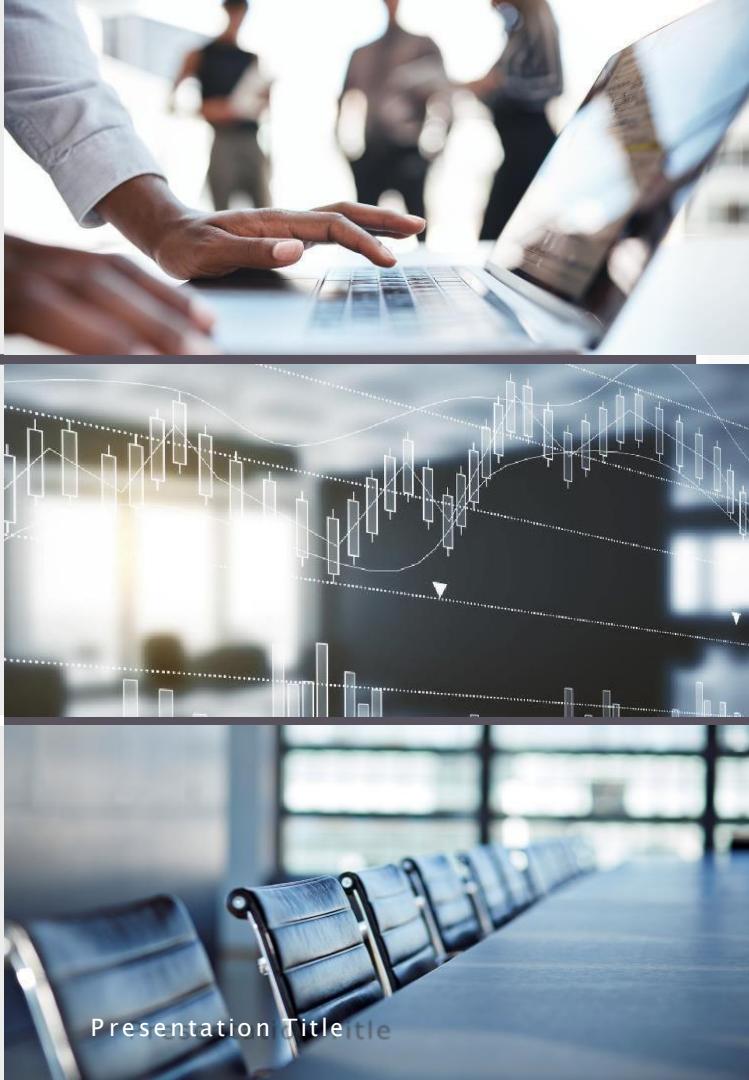
Multiple ECG Modes

Automatic Mode: In this mode, ECGs are recorded w/o operator intervention.

This is excellent for screening several patients fast in mass health camps or busy clinics .

Manual Mode Recording:

For patients who need a more extensive ECG analysis, the arrhythmia or manual mode allows medical practitioners to record and capture data over a longer period .



Summary

The MAC 400 ECG exemplifies frugal innovation by seamlessly merging efficiency and cost-effectiveness in healthcare technology. Its compact design optimizes space, and battery-powered operation ensures uninterrupted performance. With an intuitive interface and network connectivity, it reduces training needs and enhances data management. This innovation extends machine life, curbs maintenance, and slashes paperwork for tangible savings. The MAC 400 sets a new standard, demonstrating how smart design harmonizes technology and economy, shaping a streamlined, resource-wise era in healthcare.

Tractor for Agri-farming developed with **Affordability (Frugal) Engineering**

- Small range Diesel engine operated tractor, ‘KrishiShakti’ enabling farm mechanization in an affordable manner has been developed by CSIR – CMERI (Central Mechanical Engineering Research Institute). This low-cost, compact and easily manoeuvrable tractor, perfect for small size lands, is for farming and transportation.



VANRAJ MINI TRACTOR

A FRUGAL INNOVATION





Purpose

- **84%** of the Indian farmers are small and marginal, and **82%** of them lack access to modern farming equipment like tractors.
 - Overlooking the sub-**20** HP mini-tractor segment in favor of larger farms misses opportunities in key agricultural states like Gujarat, Madhya Pradesh, Maharashtra, and Uttar Pradesh with significant tractor sales.
 - Limited land area for small and marginal farmers necessitates tailored farming solutions, reducing the efficiency of large tractors.
 - 'Chhakdo' three-wheeler taxi adaptation inspires the creation of a three-wheeler tractor for innovative agricultural applications.
 - Vanraj offers cost-effectiveness and a lifespan of **8 to 9 years**, providing small farmers with efficient mechanization without significant financial strain.
- 

Market-Size and Trend

- Currently, the Indian tractor industry is estimated at **6.5 billion rupees**
- Market Segment is divided into **20 to 30 HP, 31 to 40 HP, 41 to 50 HP**, and more than **50 HP**.
- Indian contribution is about **30%**, the largest in the world.
- The **31 to 50 HP** group accounts for over **80%** of tractor sales.
- Both the > 50 HP and the 20 HP segments have had strong growth over the last ten years (F10 to F20)
- Currently, the mini tractor segment forms about a **5%** share But has a huge Potential



Pros

- The major advantage of the Vanraj mini tractor is its **affordable** price for small and marginal farmers. Vanraj and other big tractors have an equal **8 to 9 years** lifespan.
- The **fuel consumption** of 'Vanraj' is only **1.5L** of diesel, whereas the big tractors consume over 4 liters per hour.
- Vanraj can fulfill similar roles as big tractors in **material handling activities** in industries, airports, and municipalities with little modifications. It also has a hauling capacity of **2 tonnes** trailing load.
- Vanraj is a 'single piece casting' tractor with a simple design that helps in easy repairs and maintenance, even a local mechanic can repair and service it.
- Vanraj was the first mini-tractor with a tested **Power Take-Off** (PTO) point, which enables an alternate use of a tractor's engine as a **power generator**.
- It could reach small corners of land inaccessible to big tractors. It also had an **adjustable wheelbase** that suited interculture operation in various crops.

- Vanraj provides a cost-effective alternative to bullocks, typically costing around 30,000 rupees for each pair. Bullocks require year-round care, including feeding, cleaning, and shelter upkeep, costing 20,000 rupees annually for grain.
- Bullocks useful lifespan is 8-10 years. Whereas vanraj tractors offer farmers improved functionality, versatility, and convenience.
- Vanraj is more durable than comparable mini-tractors with chassis-mounted engines.
- Vanraj is tested against hostile conditions to overcome problems such as overheating, belt failure, clutch failure.

Cons

- Due to their smaller size and lower horse power mini tractors take more time as compared to big ones.
- They are not suitable for heavy duty tasks and large scale farming operations.
- They may struggle with challenging terrains limiting their usefulness in certain agricultural settings.

How is it Frugal?

- Targets the majority of small and medium farmers (**84%**) who form the Base of the Pyramid (BOP).
- Affordable (**₹ 0.19 million**) but at the same time ensures quality with low maintenance Costs (**10-15%** of SP) and with low diesel consumption (**1.5 liters** per hour); hence, it minimizes the use of resources.
- All the farming implements, albeit of smaller size, could be used with Vanraj.
(Does not compromise utility).
- It is the first tractor with a “**three-wheel convertible feature**” for which M/s Pramal Farmatics had applied for a patent in the US. Three-wheel convertibility is a valuable option for farmers, which reduces soil compaction (Added functionality).
- The above points demonstrate that Vanraj Tractor aligns with the definition of a Frugally Engineered product.

TATA Nano: One of the most referred frugal engineering outcomes is the world's cheapest car

The aim of the design features presented is to lessen complexity of procurement and production processes and considerably lowering of costs.

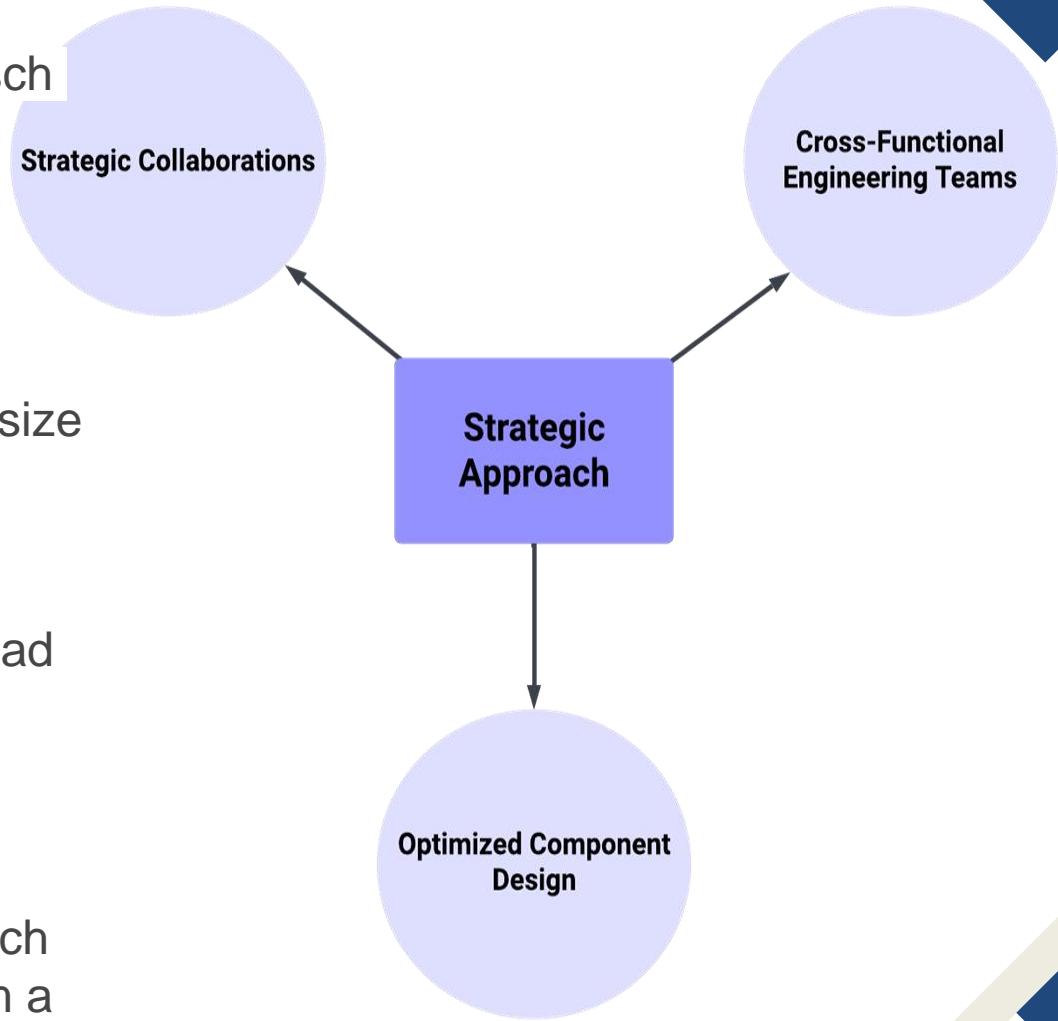


Strategic Approach

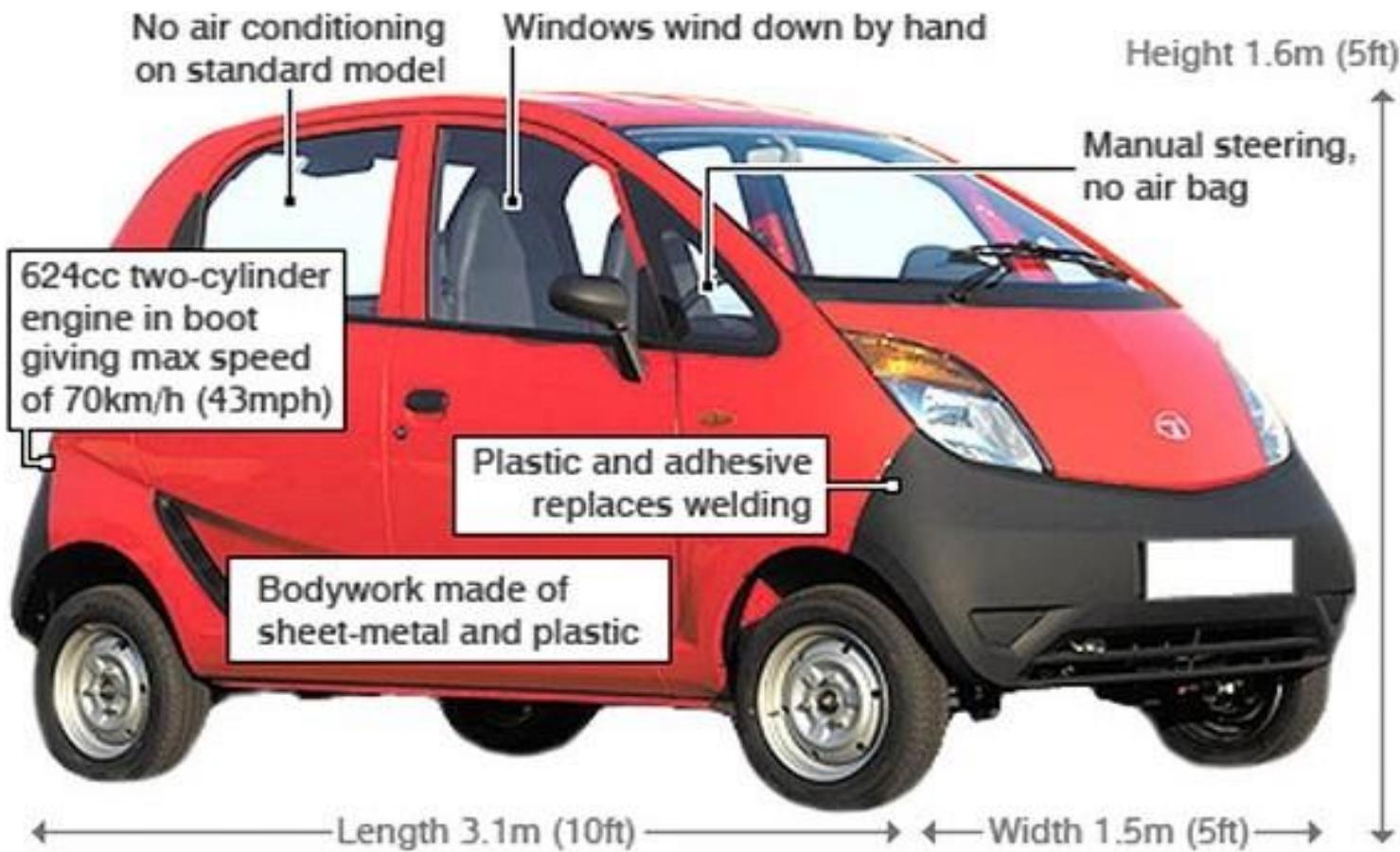
Internal and external hires,

Strategic collaboration with Bosch of Germany, Madras Rubber Factory, Denso Japan

- Bosch of Germany, streamlined non-essential functions, cutting software size
- Madras Rubber Factory, provided robust rear tires suited for India's diverse road conditions.
- Denso Japan, created a **single-wiper windshield** system rather than two which further gave the Nano team a cost advantage.



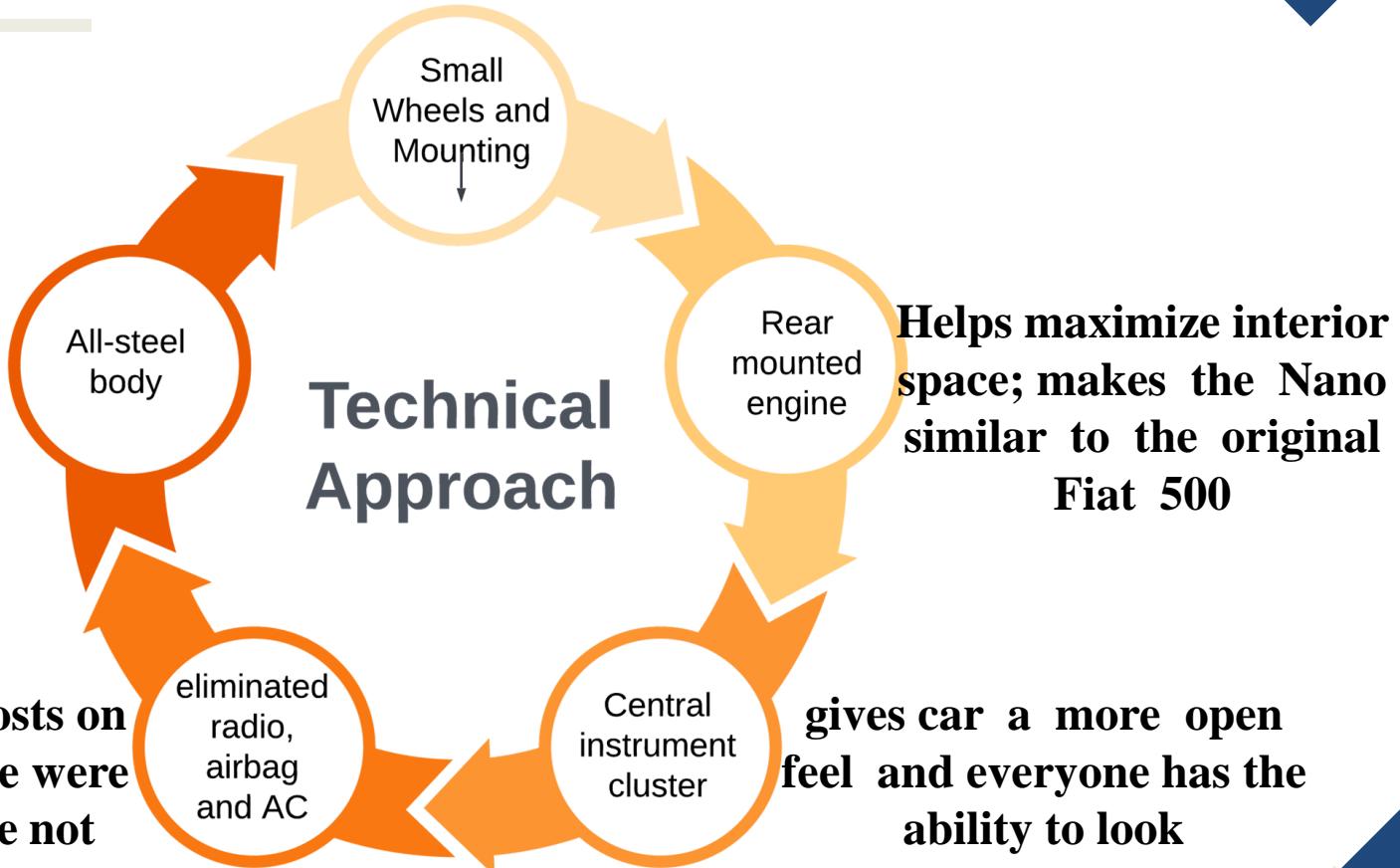
What makes it so cheap?



Small wheels which are lighter, which positively impact economy, performance and ride quality.

Less weight and fewer parts contributed less raw material and lower cost

Reduced average costs on basic models as these were functions that were not entirely important



Cost Analysis

- The Tata Nano's ₹1 lakh price made car ownership affordable for many
- Tata Nano: Affordable materials, efficient production.
- Compact, resource-efficient design prioritized safety, functionality, and cost-effectiveness
- Mass production strategy, lowering the per unit production cost

Tata Nano - World's cheapest car

Dimensions & Capacity:

- Price: \$2,000
- Launch: March 23
- Height: 1.6 m
- Length: 3.1 m
- Width: 1.5 m
- Capacity: 5 people

Features & Specifications:

- Cost saving: Single windshield wiper; no air conditioning, radio, power steering
- Safety: All sheet-metal body, intrusion-resistant doors, seat belts
- Top speed: 105 kph
- Fuel efficiency: 20km/litre
- Rear-mounted engine: 2-cylinder petrol, 623 cc

Top 5 world's cheapest cars

Company	Model	Manufactured	Price
Tata Motors	Nano	India	\$2,000
Chery Automobiles	QQ3	China	\$5,000
Suzuki-Maruti	M800	India	\$5,200
Geely Automobiles	Merrie Star	China	\$5,500
Geely Automobiles	S-RV mini SUV	China	\$5,780

Siemens Multix Select DR (X-Ray Machine)

- At nearly one third the price of the products within portfolio
- Due to rising cost pressures and a competition, healthcare providers want a budget-friendly solution for good-quality general radiography. It is a floor-mounted digital X-ray machine that combines facilities and features namely, cost-effective room setup with a high level of clinical flexibility.
- Outstanding image quality is achieved by selecting from best technologies. It provides greater financial flexibility with a digital X-ray machine that offers expert solutions for general radiography in an economical way.



Multix Select DR - Your expert in Economical Digital Radiography

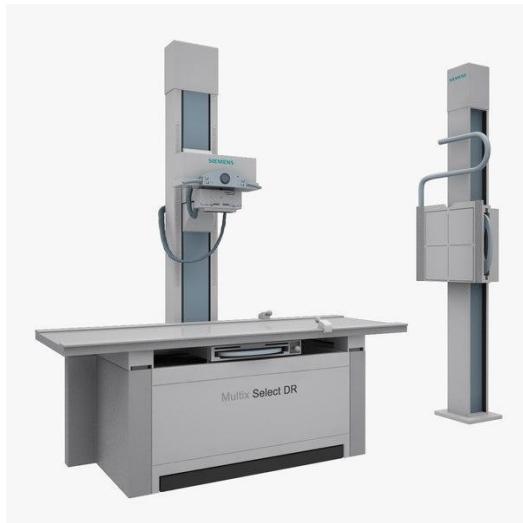
Multix Select DR is a floor-mounted digital X-ray machine that combines cost-effective room setup with a high level of clinical flexibility.

With its reliable machine components it enables one to examine patients from head to toe for coverage up to 190 cm without the need to reposition the patient.

The Multix Select DR digital X-ray machine facilitates a comprehensive range of both general and specialized medical exams, including chest and orthopedic studies, standing and weight-bearing imaging, as well as free examinations conducted on mobile trolleys or for patients in wheelchairs.



Frugality of the Product



First time digital

For the first time, film becomes dispensable – eliminating the manual hassle and use of chemical materials.

First time that fast

For the first time, one can see images in 9 seconds instead of minutes – that's image turnaround with Multix Select DR.

First time that economical

For the first time, one can get innovative technology engineered at an entry level – including proven functions and components from the high performance X-ray products.

Features of Frugal Version

- 1. Digital Technology:** The Multix Select DR utilizes digital flat-panel detectors (FPDs) instead of traditional film, reducing ongoing costs associated with film, chemicals, and processing. It can be stored electronically eliminating film storage and transportation costs and can be easily shared with other healthcare providers through Picture Archiving and Communication Systems (PACS).
- 2. Faster Image Acquisition:** Digital radiography systems like Multix Select DR offer faster and immediate image acquisition enabling quicker diagnosis and treatment decisions improving patient outcomes and patient throughput and reduce labor costs and hospital stays.
- 3. Reduced Radiation Dose:** Advanced features like automatic exposure control (AEC) optimize radiation dose for patients, reducing the risk of unnecessary radiation exposure and potential complications and also helps facilities manage radiation dose-related costs and compliance, while improving safety
- 4. Improved Image Quality:** Digital technology allows for image enhancement and manipulation, reducing the need for repeat exposures and improving diagnostic accuracy.
- 5. Versatility:** The system's flexibility in terms of patient positioning and examination types allows for a wide range of radiographic procedures, potentially reducing the need for multiple specialized systems.
- 6. Energy Efficiency:** The product is designed to be energy-efficient, which can lead to reduced electricity costs over time.

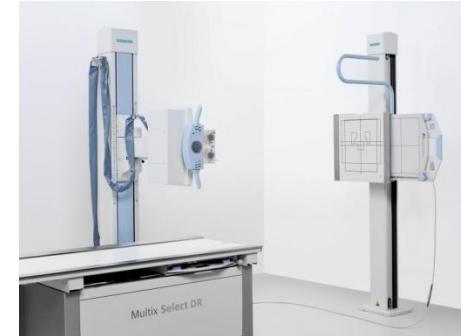
Fetal Heart Monitor and Frugal SMART products from Siemens

- **Siemens**, the Germany based industrial conglomerate through its **R&D centres in emerging economies (India and China)**, developing frugal solutions for delivering better value to consumers. **Siemens' engineers at Indian centre, in collaboration with their German counterpart** have developed a Fetal Heart Monitor, designed with **inexpensive microphone technology instead of using ultrasound technology**, which is pricy.



US \$200 billion global market for **SMART** portfolio

- This Fetal Heart Monitor, affordably engineered, is part of **Siemens'** expanded portfolio of frugal solutions, classified as '**SMART**' (**S**imple, **M**aintenance-friendly, **A**ffordable, **R**eliable, and **T**imely-to-market). **SMART** products are about **50 percent cheaper** than conventional high-end solutions.
- Those are also easier to implement besides being energy-efficient and its popularity can be guessed from the company's estimate of a **US\$200 billion global market for SMART portfolio**.



- According to Peter Löscher, CEO of Siemens, “Scarcity of resources is not an impediment but an enabler (of innovation).” as reported by N. Radjou.

Jaipur Leg/ Jaipur Foot

- A low cost prosthetic ‘Jaipur leg’ developed in India, costs only about \$150 to produce, that embodies improvisations by adapting irrigation piping into the design to reduce cost.



Dr. PK Sethi and Master Ram Chandra Sharma
Inventors of the Jaipur Foot





JAIPUR FOOT

Crafted by leveraging indigenous materials like Rubber & wood and hand tools for preparing & assembling

Use of locally sourced, affordable materials and its repairable design, which reduces the need for constant replacement, ultimately minimizing environmental impact while providing long-term solutions for amputees

The design is simple, requiring fewer components and intricate mechanisms. This simplicity not only eases manufacturing but also reduces the chances of breakdowns, lowering maintenance costs for the user.

The Jaipur Foot's adaptability ensures users a personalized, comfortable solution by customizing it to fit their needs. Providing effectiveness, this quality enhances its overall value as a prosthetic technology.

The 'Foot' has a long track record of successfully restoring mobility to amputees. Its simplicity doesn't compromise its ability to provide efficient and comfortable walking, as evidenced by the numerous testimonials from users who have experienced improved quality of life.

The creators have maintained a user-centered approach, ensuring that the prosthetic addresses the real needs and challenges amputees face. This approach naturally steers the design away from unnecessary features that might contribute little to the core functionality.

The 'Jaipur Foot' was constructed utilizing rubber, plastic, and wood, as opposed to most prostheses at the time, composed of carbon fiber. Because of the drastically reduced production costs-only, \$150 was needed to create each prosthetic-working people could finally buy them.

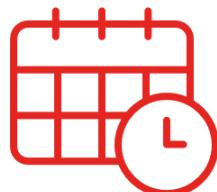




Data-backed Analysis

Limb Restoration and Empowerment

Jaipur Leg works to enhance the lives of around 16000 people each year in India, where the number of people living with a leg amputation is approaching 25000, constant efforts are made to reduce this disparity.



Stable Design

The knee lasts the average person around 3.7 years before replacement.



Imminently Real

The average weight of the prosthesis is kept around 3.11 kg to maximize the leg's adaptability, keeping in mind that a 55-kg person's lower limb typically weighs roughly 3.36 kg.



Future Enhancements

The fourth generation of this knee, costing US\$20 to manufacture, is currently in use, and 7,500 have been fitted to patients in India with excellent results.

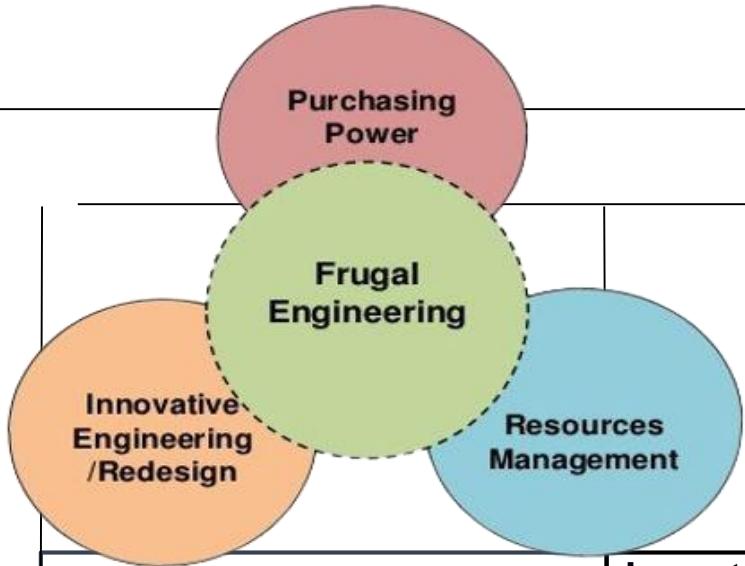
Infant Warmer/ Incubator designed at Stanford University

- ‘Embrace’, designed at Stanford University in the US, where a team of graduate students ideated for creating an **inexpensive infant warmer**, used as **incubator**, that functions as a low-tech device.
- Embrace has the potential to **save thousands of babies** in the **developing world**.





Infant Warmer and the Frugal Engineering Context



What is frugal Innovation?

It is all about doing more with less. It is innovation born out of necessity, driven by the need to provide affordable, accessible, and sustainable solutions to pressing challenges, especially in resource-limited settings.

importance of affordable infant warmers in healthcare?

Affordable infant warmers are crucial for newborn care and increase healthcare accessibility, especially in underserved regions. They prevent hypothermia, reduce infant mortality, and aid development, lower infection risks, are cost-effective,

How is Embrace Infant Warmer a Frugal Innovation?

It demonstrates frugal innovation by offering an affordable, user-friendly solution for premature infant care. Its simplicity, energy efficiency, portability, and focus on critical needs exemplify the core principles of frugal innovation in healthcare.



BUY CHEAP

Designing affordable efficient infant warmer



Traditional Expensive Incubators

Embrace's Frugal Infant Warmer

HighTech Design

- Plexiglas to watch babies easily
- Hinged hood
- small openings for care
- Temperature control by coils or tubes with electronic regulators
- Hygrometers for Humidity control
- Oxygen can be added from outside
- Safety alarms protect babies
- Expensive material

Simpler Design

- Originated in a Stanford class
- Human Centered Reframing with a focus on end users
- Design consists of a paraffin-based phase-change material (PCM) incorporated into a sleeping bag design.
- Use of PCM? (regulates baby's temperature without electricity for an extended period of time)



Why the need for frugal Infant Warmers?

The Challenge

- ❑ Each year, 20 million premature and low-birth-weight babies are born and have high mortality rates in developing countries due to the scarcity of incubators.
- ❑ New incubators are costly, and donated ones are difficult to operate and maintain
- ❑ The challenge: design an affordable and effective incubator for the developing world



Insight

- ❑ The Embrace team started research in Kathmandu, Nepal
- ❑ Discovered that most premature Nepalese infants were born in rural areas with limited access to hospitals
- ❑ Realized that their design had to be portable, electricity-free, intuitive, sanitizable, culturally appropriate, and most importantly, inexpensive



Feature Altered

Features removed

Transparent Cabinet

Sophisticated
Temperature Control

Humidity Control

Oxygen Control

Airflow Control

Alarms

Features added

Phase-Change Material

Portability

Affordability

Ease of Use

Wrap Design

Ease of Maintenance



Manufacturability

Standard Incubator:

- Complex electronics and precise control systems make them costly and technically intricate to manufacture.
- rely on imported parts, increasing the cost of production.



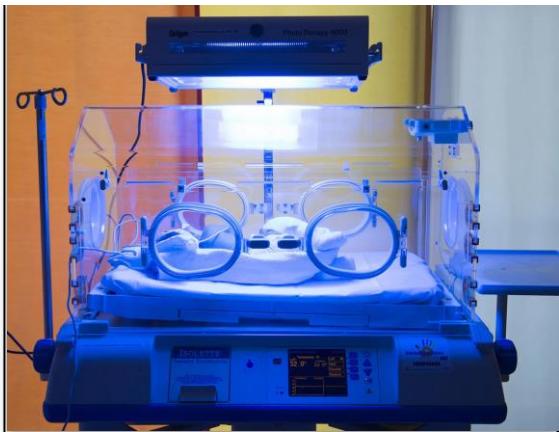
Embrace Infant Warmer:

- simple design based on phase-change materials, making them relatively easy and cost-effective to manufacture.
- Local production can be viable, reducing reliance on imports.

Affordability

Standard Incubator:

- prohibitively expensive, around \$20,000 or more.
- High costs limit accessibility for healthcare facilities in low-resource areas.



Embrace Infant Warmer:

- exceptionally affordable, costing only \$25 per unit.
- Designed to be accessible to even the most resource-constrained healthcare facilities.



User Centric	Embrace Infant Warmer:
Standard Incubator: <ul style="list-style-type: none">Complex controls and settings demand specialized training, increasing the learning curve.User-friendliness is not a primary focus, leading to potential challenges in operation.	<ul style="list-style-type: none">prioritizes user-friendliness with an intuitive design, reducing the need for extensive training.aligns with local practices such as "Kangaroo Care," fostering user-centric care.
Sustainability	
Standard Incubator: <ul style="list-style-type: none">resource-intensive due to their reliance on electricity, resulting in high operational costs.Their carbon footprint can be substantial, especially in regions with unreliable power.	Embrace Infant Warmer: <ul style="list-style-type: none">sustainable as they don't rely on electricity, reducing operational costs and environmental impact.Reusable phase-change materials contribute to sustainability.





Portability

Standard Incubator:

- Bulky and stationary.
- Requires a stable electricity supply and infrastructure.

Embrace Infant Warmer:

- small and light
- Ideal for use in remote or resource-limited areas.

Infant

Ease of Maintenance

Standard Incubator:

- intricate maintenance procedures due to their electronic components.
- Skilled Technicians are required.

Embrace Infant Warmer:

- easily sanitized by boiling reducing the complexity.
- straightforward maintenance contributes to lower operational expenses



Functional

Standard Incubator:

- technologically advanced, providing precise control over environmental factors like temperature and humidity.
- However, this functionality comes at a high cost and complexity.

Embrace Infant Warmer:

- simpler and effectively maintain a stable temperature for premature infants.
- fulfill the essential functions needed for infant care in resource-limited settings.



Local

Standard Incubator:

- often produced by multinational companies and may not align with the specific needs and contexts of local communities.
- limited local production or customization.

Embrace Infant Warmer:

- can be adapted and produced locally, increasing relevance and customization for the communities they serve.
- strong focus on local integration and cultural appropriateness.



‘Embrace’ in a Nutshell

- ✓ **Designed with frugality in mind to address resource limitations in healthcare settings.**
- ✓ **Utilizes phase change material (PCM) for temperature regulation.**
- ✓ **It's lightweight and compact design enhances portability in a low cost.**
- ✓ **User-friendly interface for easy operation by healthcare professionals**



The Embrace Infant Warmer embodies innovation, affordability, and accessibility in neonatal care. This warmer stands as a testament to technology's power to enhance global healthcare and nurture healthier beginnings for infants worldwide.

A Chinese Example: X-ray machine, Zhongxing Medical

- Principle adopted: BORROW and REUSE
 - Innovation: By Re-engineering an underused technology (in an aerospace company in Beijing) to build equipment costing only \$20 K compared to \$150K models of GE and Philips.
- 
- To achieve this, a trade-off was made. Rather than engineer the equipment for wide range of sophisticated scans (common in Western hospitals), it focused on a device to perform only the chest scans, the vast majority among scans. Understanding the primary needs of its target hospitals, those cannot afford a conventionally priced X-ray m/c, the product was built.
 - The company developed a digital direct X-ray (DDX) equipment-product based on 'line-scanning' technology acquired from its parent company (Beijing Aerospace) via a Russian partner, that was regarded obsolete by GE and Philips, the then market leaders in this area. This captured 50% of China's X-ray market, compelling GE to cut prices by half and Philips to exit.
 - Chinese companies, in general, have applied cost innovation into three areas: (1) high technology at low prices; (2) product variety at mass-market prices; and (3) specialty products at low prices.

India is where Prof. Amos Winter of MIT developed an all-terrain wheelchair, and it's the country that acts as a real-world laboratory for him. Here, the consumer earnings are less, has a different culture, and hence he tries to capture those factors and combine it with the engineering theory to create low-cost, high-impact technologies at the Global Engineering Research Lab (GEAR) of MIT.

(<https://www.fastcompany.com>)

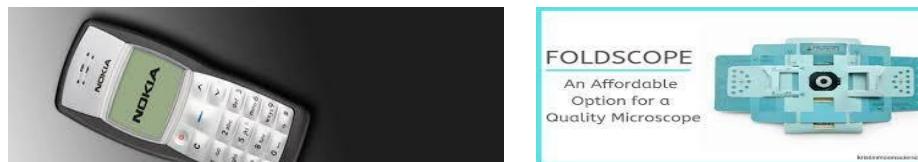


Some more examples.....to understand Unique Value Proposition

- **ChotuKool fridge:** A tiny refrigerator ‘ChotuKool’, sold by Godrej Ltd.(India) the may have more in common with cooling system used for computers unlike other refrigerators; it removes the traditional compressor for a computer fan.



- **Foldscope:** Designed at Stanford University to cost no more than a US dollar, the Foldscope is a non-fragile origami microscope assembled from a sheet of paper and a lens.



- **Nokia 1100:** Designed for developing countries, using basic features besides being durable. More than 200 million units got sold in only four years after its introduction in 2003 as one of the best selling phones of all times.



- **Aakash Internet Tablet:** Developed by a technology company ‘Datawind’ for Indian government to provide low-cost tablets to students in India.

NEED FOR CHOTUKOO L



**One-Third of all food produced in India
is lost to spoilage**

**70% of rural India does not have
access to electricity**

**Refrigerators in market are expensive
(>Rs 7k)**

**High operational cost of traditional
refrigerators**

**Traditional systems are bulky and
inefficient**

KEY FEATURES



45-litre plastic
container for
cooling food



Operates on a
12-volt battery



Solid-state cooling
technology



"Just right"
philosophy



Boosting rural
income through food
preservation

WHAT MAKES IT 'FRUGAL'

LOW MAINTENANCE

its simple design requires minimal maintenance and repair, reducing long-term ownership costs

AFFORDABILITY

makes it accessible to lower-income households, providing a cost-effective refrigeration solution

ENERGY EFFICIENCY

helps users save on electricity costs, particularly in areas with unreliable power supplies

STORAGE

with smaller storage capacity, it reduces food wastage, saving consumers money and benefiting the environment

PORTABILITY

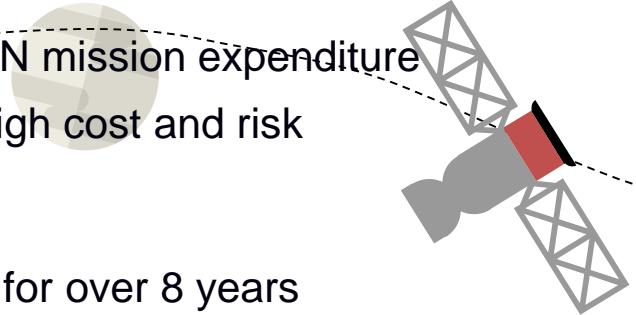
is a significant advantage in regions where people frequently move or have limited access to electricity

What makes Mangalyaan Frugal ?



Cost Comparison

- Total cost - 80 million USD, only 10% of NASA's MAVEN mission expenditure
- Mission successful in first attempt - remarkable given high cost and risk



Mission Duration and Success

- Mission duration - 6 months, but successfully operated for over 8 years
- 16-fold mission life extension, showcasing durability without much loss to quality



Payload and Instruments

- Instruments like MSM, MENCA provided crucial scientific data about Mars
- Collected data invaluable for future missions - more scientific yield per investment

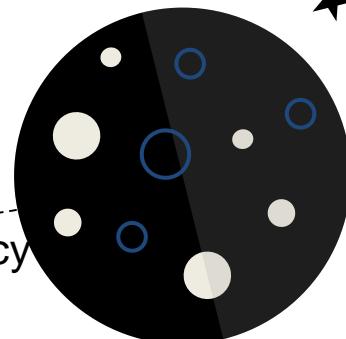
Launch Vehicle

- Mangalyaan launched using 'Polar Satellite Launch Vehicle (PSLV)'
 - PSLV's high success rate contributed to cost-effectiveness launch



Modular Design

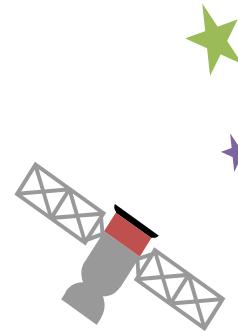
- Modular design allowed efficient integration and testing of components
- This reduced assembly time by 25%, improving overall mission efficiency



What makes Mangalyaan Frugal ?.....Contd.

Propulsion System

- Propulsion system used a liquid apogee motor and chemical thrusters
- This minimized fuel consumption by 30%, optimizing resource utilization



Innovative Solutions



- Gravity Assist Manoeuvre reduced fuel usage by 30%, while attaining Mangalyaan's escape velocity
- This innovative maneuver significantly lowered energy expenditure, showcasing frugal problem-solving

Ground Operations



- Using existing infrastructure reduced costs by 15%, avoiding need for new facilities
- This approach ensured cost savings without compromising mission operations

International Collaboration

- Partnership with NASA for communication support saved 12% of mission expenses
- This international partnership showcased cost-effectiveness through resource sharing



ISRO's Frugal MoM; Low-cost (80 Million USD) Spacecraft, Mangalyaan, for Mars Orbiter Mission (MoM) with an outlay of only 10 %, compared to MAVEN, built by NASA. It is based on Frugal Engineering, as it adopted available technology as much as possible. The concept was that instead of directly flying to Mars, the vehicle would orbit the earth for about a month, building up velocity to slingshot its way out of earth's gravitation to embark on its 400 million kilometre journey. The quality and reliability has not been compromised - the Mangalyaan mission, which was initially meant to last six months, has completed five years of orbiting Mars and is likely to continue for some more time.....

