



# ***Engineering Research & Development Methodology***

## **Basic Concepts in R&D**

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Elias Lemuye (MSc)  
SoEEC / CSE Program



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Adama Science & Technology University

# Basic Concepts in R&D

- **Engineering**
- **Engineering & Technology**
- **Research & Development**
- **Research & Innovation**
- **Importance of R&D**
- **Role of Government in R&D**
- **Reflective Thinking**



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# Engineering

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# What is Engineering?

- The concept of engineering was derived from the dawn of human history
  - Our ancestors **developed** & **designed** tools that were essential for their survival.
  - Human beings can be defined by
    - their **tool-making**, **designing** & **engineering skills**, &
    - the socialization & communication that facilitated the invention, innovation & transfer of technology.
  - This activity is similar to the modern idea of engineering where **trial** & **error** is an important part of innovation.



# What is Engineering?

- Engineering is the field or discipline, practice, profession & art that
  - relates to the **development, acquisition & application** of technical, scientific & mathematical knowledge
  - about the **understanding, design, development, invention, innovation & use** of materials, machines, structures, systems & processes for specific purposes.
- Engineering in the modern sense relates to **art**
  - appreciated in the creativity & elegance of many engineered objects & structures
  - **Example** : objects & structures of art exhibitions.



# What is Engineering?

## Fields of Engineering closely related with CSE

### ■ Computer & Systems Engineering

- Research, design & development of computer, computer systems & devices.

### ■ Electrical Engineering & Electronic Engineering

- Research, design & development of electrical systems & electronic devices.

### ■ Software Engineering

- Research, design & development of computer software systems & programming.



# What is Engineering?

- Engineering connects to the **natural sciences**, & to the **social & human sciences**.
  - Engineers use both scientific knowledge & mathematics to create technologies & infrastructure to address human, social & economic issues.
  - Engineers connect social needs with innovation & commercial applications.
  - Technological change & innovation is
    - one of the major drivers of economic, social & human change,
    - so engineering & technology & the social sciences are more closely connected.



# What is Engineering?

## ■ Engineering powered the **Industrial Revolution**

- took off in the UK in the 18th C spreading to the world,
- replacing **muscle by machine** in a synergistic combination between knowledge & capital.

- The 1st Industrial Revolution (1750–1850)

- focused on the **textile industry**

- The 2nd Industrial Revolution (1850–1900)

- focused on **steam & the railways**

- The 3rd Industrial Revolution (1875–1925)

- based on steel, electricity & heavy engineering

- The 4th Industrial Revolution (1900–1950)

- based on oil, the automobile & mass production

- The 5th Industrial Revolution (from 1950)

- based on information & telecommunications

➤ The revolutions happened mainly due to Engineering R & D too





# What is Engineering?

- The great days of engineering were in the past
  - during the era of **massive mechanization** & **urbanization** that had its heyday in the 19<sup>th</sup>C
  - improved the health & well-being of the common person with improvements in water supply & sanitation.
- That era of great engineering enjoyed two advantages:
  - seemingly unlimited sources of power, coal, oil & gas, &
  - boundless capacity in terms of water supply, materials & other resources relative to human need.



# What is Engineering?

- The tasks confronting engineers of the 21<sup>st</sup> C are:
  - **Climate change**: engineering the world to avert an environmental crisis caused in part by earlier generations in terms of energy use, greenhouse gas emissions & their contribution to climate change, &
  - **Poverty reduction**: engineering the large proportion of the world's increasing population out of poverty, & the associated problems encapsulated by the UN MDGs.
- Resolving these issues will require tremendous innovation & ingenuity by engineers.
  - It demands **Engineering R&D**



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# **Engineering & Technology**

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# Engineering & Technology

- Technology is an enabling **package** or **tool** formed of knowledge, devices, systems, processes & other technologies created for a specific purpose.
- It is the engineering process that creates technology, & which makes technology useful to people.
- Technological change is a complex process that must be managed all the way from concept to the market place.
  - Researchers in technology would be well advised to address customer & societal needs & market requirements & not just research for research or technology's sake.



# Engineering & Technology

- Thus, questions to be considered include :
  - What is the societal problem?
  - What is the technological challenge?
  - What is the business driver?
  - How to define the research project?
  - What are the findings/results?
  - What are the potential applications?





"I know R&D feels that the product warrants at least two 'reallys'."

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## Research & Development (R&D)

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# R&D

- R&D refers to two intertwined processes of
  - **research** (to identify new knowledge & ideas) &
  - **development** (turning the ideas into tangible products or processes).
- R&D can be defined as
  - the process of creating new products, processes & technologies that can be used & marketed.
- The OECD defines R&D as
  - “creative work undertaken on a systematic basis in order to increase the stock of knowledge of man, culture & society, & the use of this stock of knowledge to devise new applications.”



# R&D

- In order to provide functional & understandable definitions for various research activities, **Science Indicators** categorizes R&D activities as efforts in science & engineering as follows:
  - Producing significant advances across the broad front of understanding of natural & social phenomena—**basic research**
  - Fostering inventive activity to produce technological advances— **applied research & development**
  - Combining understanding & invention in the form of socially useful & affordable products & processes— **innovation**





# R&D

- The National Science Foundation (NSF) classifies research as (*Science & Engineering Indicators*, 2008):

- **Basic Research**

- Objective : “a more complete knowledge or understanding of the subject under study, without specific applications in mind.”

- **Applied Research**

- To gain “knowledge or understanding to determine the means by which a specific, recognized need may be met.”
- includes investigations “to discovering new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.”



# R&D

- The National Science Foundation (NSF) classifies ...
- **Development**
  - the “systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems or methods, including design & development of prototypes & processes.”
- R&D covers many of these activities.



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# **Research & Innovation**

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# Research & Innovation

- Innovation is often associated &/or confused with the word *research*.
- Undoubtedly, research & innovation are part of an integrated, iterative feedback loop, where the creation & discovery of knowledge stimulate innovation, which, in turn, produces new stimuli & requirements to drive & enrich the research agenda.
- However, even if strongly related to each other, research & innovation do have specific differences & characteristics that need to be carefully assessed & understood.



# Research & Innovation

- Research is the **creation of knowledge**, whereas innovation is the **application of research results** to create new processes, products, & services.
- In research, the focus is on **knowledge creation & discovery**; in innovation, the focus is **on transforming knowledge into something usable** by someone operating in a specific market or, in general, in some part of society.

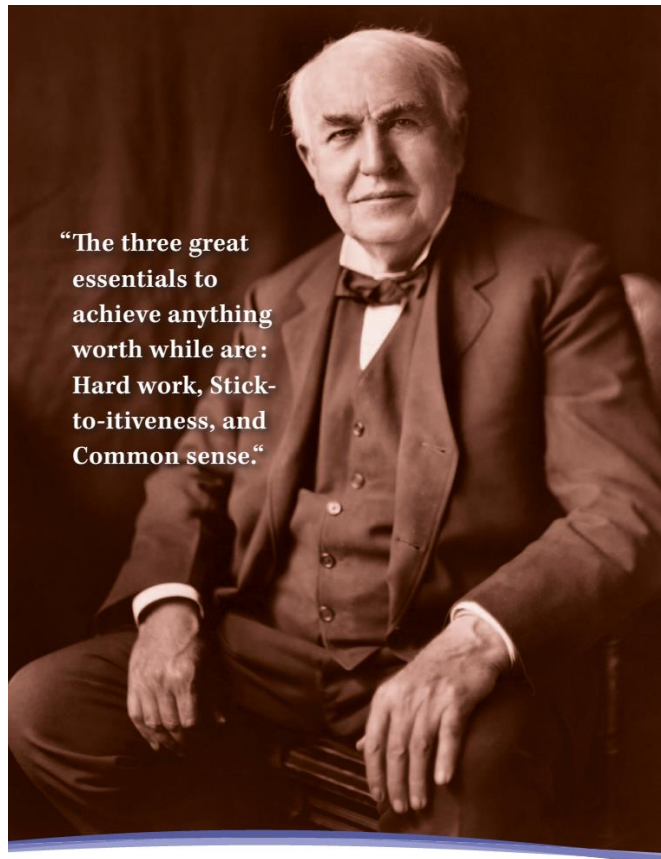


# Research & Innovation : Example 1

- Edison **invented** the lightbulb in 1879.
  - It was a brilliant, historic result that has changed our lives forever. However, 19<sup>th</sup> C towns didn't have a power grid, which was not even a concept at that time.
- To bring it to the market, Edison formulated the electric power distribution grid & a company to build & manage it. Eventually, in 1882 Edison was able to bring his new service to 59 customers in Manhattan.
  - In general, Edison's invention took years to materialize across the whole society, as it demanded the creation of a totally new industry & business sector.



# Research & Innovation : Example 1



## THOMAS EDISON

- *(Feb 11, 1847 – Oct 18, 1931) was an American inventor & businessman.*
- *He developed many devices that greatly influenced life around the world, including the **phonograph**, the motion picture **camera**, & a long-lasting, practical **electric light bulb**.*
- *Edison is the fourth most prolific inventor in history, holding **1,093 US patents** in his name, as well as many patents in the UK, France, & Germany.*



# Research & Innovation : Example 1

- Edison is known as an inventor, but he was also a great innovator.
  - an **invention** brings an idea into tangible reality by embodying it as a product or system.
  - An **innovation** converts a new idea into revenues & profits.
  - For an invention to become an innovation, people must be willing to buy it in high enough numbers that the firm benefits from making it.
  - Edison's lab was an **applied research** lab, which is a lab that develops & commercializes its research findings.





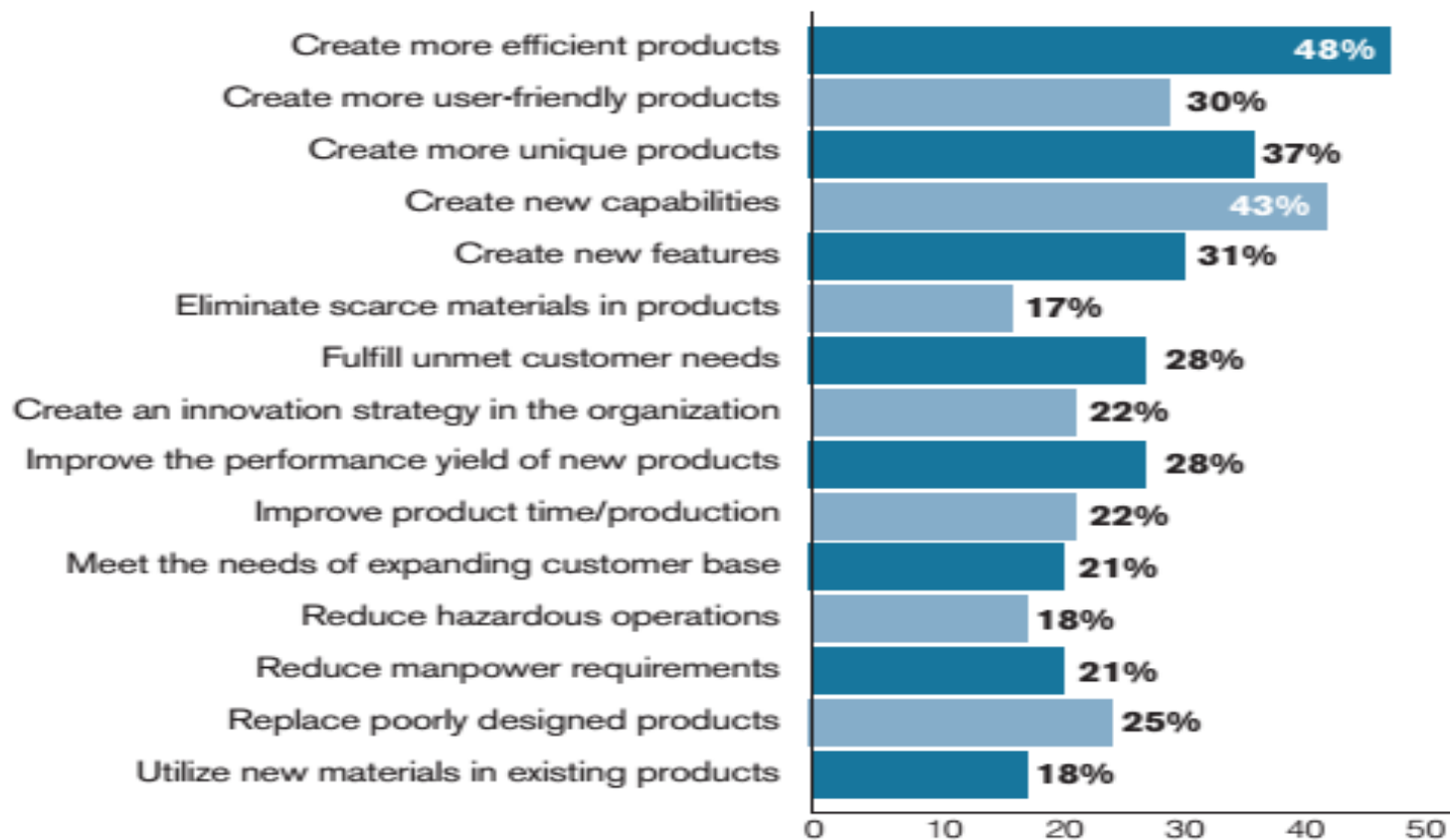
## Research & Innovation : Example 2

- In the 1960s, object orientation was a purely research result that had no practical impact.
- In the 1970s, Xerox PARC (Palo Alto Research Center) launched **Smalltalk**, which had a huge impact in the research community, but a limited market success.
- Eventually, the knowledge accumulated over the years was exploited in the 1990s, with development of a new breed of programming languages & systems, & bringing object orientation to market success with C++ & later with Java.



# Research & Innovation

## Primary Industrial Organization Innovation Goals



Source: R&D Magazine Survey 2017



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# **Importance of R&D**

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# Importance of R&D

## The Global R&D Outlook

*Global R&D spending has continued its steady climb with more than **\$2 trillion** being invested for the third consecutive year in 2018.*

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*More than two-thirds of all global R&D investments are supported by industrial organizations. Of these industries, **ICT is expected to be the main driver of innovations** among all of them over the next ten years.*

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*Artificial intelligence, automation & robotics & associated software involved in ICT will change the overall R&D environment—& much of society—by the mid-2020s.*

Bea Riemschneider  
Science Editorial Director  
*R&D Magazine*  
[www.RDmag.com](http://www.RDmag.com)



# Importance of R&D

- Companies undertake R&D in order to **develop new products, services, or procedures** that will help them grow & expand their operations.
- Companies invest in R&D to gain a pipeline of new products.
  - For a high-tech company like Apple, it means coming up with new types of products as well as newer & better versions of its existing computers & iPhones.
- From investing in R&D, the nation's economy benefits as well
  - in the long run, growth in GNP per worker is due more to technological progress than to mere capital investment.



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# **The Role of Government**

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# The Role of Government

- Governments can play a big role in innovation because of their ability to **fund R&D**.
  - offering grants to universities & research centers or by offering contracts to corporations for performing research.
- Governments can also **provide tax incentives** for companies that invest in R&D.
  - For example, Australia gave a 125 percent tax deduction for R&D expenses. The Australian government's website noted, "It's little surprise then, that many companies from around the world are choosing to locate their R&D facilities in Australia."



# The Role of Government

- Governments can promote innovation through **investments in infrastructure** that will support new technology & by committing to buy the new technology.
  - *Since 2000, China has had a policy in place **to encourage tech transfer from abroad** & to force foreign companies to transfer their R&D operations to China in exchange for access to China's large volume markets.*
  - *For example, any automobile manufacturer that wants to sell cars in China must enter into a **partnership** with a Chinese company. As a result, General Motors (GM), Daimler, Hyundai, Volkswagen (VW), & Toyota have all formed **joint ventures** with Chinese companies.*





# The Role of Government

- Governments can **set high targets** that require innovation.
  - In the 1960s, the **US Apollo space program** launched by President John F. Kennedy inspired US corporations to work toward putting a man on the moon.
  - The government's investments in the Apollo program sped up the development of computer & communications technology & also led to innovations in fuel cells, water purification, freeze-drying food, & digital image processing now used in medical products for CAT scans & MRIs.
- Governments can also play a big role in the **protection of intellectual property rights**



# The Role of Government- Ethiopia

## ■ Research & Technology Transfer

- The GoE considers investment in R&D a necessary precondition for a sustained development not only of ICT but also for scientific progress.
- In recognition of the important role that R&D transfer plays in facilitating the country's socio-economic development process in general & ICT in particular, the Government commits itself to the following specific objectives & strategies.
- **Goal:** Develop the nation's ICT R & D capacity to support, facilitate & contribute to the development of the nation



# The Role of Government- Ethiopia

## ■ Objectives

- To ensure that research projects & programs aimed at solving logical problems, meet national needs & enhance the development of professional skills.
- To support R&D transfer within research-oriented institutions.
- To harness R&D transfer capabilities & global best practices by promoting collaboration between the country's ICT centers of excellence & those of other countries.
- To encourage participation in research undertakings by ICT professionals.



# The Role of Government- Ethiopia

## ■ Strategies

- Develop an ICT R&D transfer policy & strategy.
- Allocate adequate resources /budget to R&D transfer for hardware & software development, communications, information networks, technology etc.
- Promote applied & need-based R&D transfer activities so as to increase the levels of technological innovation.
- Promote R&D transfer in areas such as
  - standard character set, language interoperability, electronic dictionaries & thesaurus uses, & multilingual search engines for widely spoken indigenous languages, in order to facilitate accessibility.



# The Role of Government- Ethiopia

## ■ Strategies

- Network R&D transfer activities conducted by public & private establishments for sharing best practices from lessons learned across sectors.
- Provide different incentives to the private sector to invest in R&D transfer activities.
- Disseminate information on new development in ICT arising from research findings.



# Reflective Thinking

- Check your understanding about Engineering, Technology , Invention, Innovation , Research , R&D, and other related concepts.
- What do you think about the argument “Researchers in technology would be well advised to address customer & societal needs & market requirements & not just research for research or technology’s sake.”?
- What benefits does a company get by investing in R&D?
- Describe the ways in which government can influence R&D.



# References

- UNESCO, 2010. Engineering: Issues Challenges and Opportunities for Development, Paris: UNESCO.
- The Federal Democratic Republic of Ethiopia (2009). The National Information & Communication Technology Policy & Strategy. Addis Ababa, Ethiopia
- 2018 Global R&D Funding Forecast : a supplement to R&D Magazine
- Jain, R. K. (2010).Managing research, development and innovation : managing the unmanageable
- Kothari(2004).Research Methodology : methods & techniques

