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A NEW MODEL FOR COMMERCIALIZATION OF NANOTECHNOLOGY PRODUCTS & SERVICES

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Abstract:

Nanotechnology innovations are making a revolution in design and manufacturing, creating new materials and products through novel processes for commercial applications. New products based on nanotechnology with novel characteristics are continued to grow and benefit the society. Being general purpose technology, nanotechnology is expected to support all fields of the society, but some fields like medicine, energy, environmental remediation, robotics, manufacturing, commerce, and space exploration are expected to undergo explosive developments. Many business organizations are monitoring such developments to encash business opportunities of nanotechnology developments by commercializing these products successfully. In this paper, we made a detailed analysis on nanotechnology applications in different fields based on business organizations point of view. Based on the business perspective, we have developed a new model for commercialization of nanotechnology products/services and analyzed it based on organizational and customer's perspectives. The paper also contains a detailed discussion on the opportunities and challenges for nanotechnology commercialization as per developed model in terms of time lag, the valley of death, lack of infrastructure, lack of a standard for evaluation, bureaucratic delays, the dearth of funding, lack of trained professionals, brand image, and public support. Finally, we have discussed the advantages, benefits, constraints, and disadvantages of this new commercialization model in terms of nanotechnology products/services market potential.

Index Terms: Commercialisations of Nanotech Products, Challenges in Commercialization of New Products & Nanotechnology Commercialization Model

1. Introduction

The business perspective of nanotechnology-based products and services are expanding day after day to many fields due to its potential ability to solve problems related to human civilizations pertaining to both basic needs and aspirations for comfort life. The basic needs of human being are food, drinking water, energy, cloth, shelter, health and clean environment. The business opportunities for solving these basic needs are almost infinite due to the reason that major parts of people living in developing countries have problems to acquire their basic needs. The aspirations for comfort life using nanotechnology also discloses many business opportunities due to the fact of realizing the automation in every field including space travel, expanded lifespan, and so on. The continuous efforts of scientists and engineers during last 30 years, created a substantial progress in realizing the business opportunities through nanotechnology-based components and products in different areas including agriculture, food product and packaging, purification of water, automobiles, atmospheric cleaning, renewable energy, energy storage, consumer goods, sports equipment, cosmetics, cloth and fabrics, construction materials, shelter, health, information communication technology, high speed manufacturing, space travel, military, sustainable environment, computer & robotic technology, and even lifespan expansion [1]. Hence nanotechnology has huge business potential in an effort of solving all social problems like eradication of poverty, a permanent solution to hunger and thirst, social evils like corruption, threats on equality etc., due toits ability to fulfill the characteristics of ideal technology [2]. Nanotechnology involves the manipulation of matter on an atomic, molecular, and supramolecular scale, and its goal is to precisely manipulating atoms and molecules for fabrication of macro scale products with business value, also referred to as molecular nanotechnology. Nanotechnology is evolving to become a general-purpose technology by 2020, encompassing four generations of products with increasing structural and dynamic complexity: (1) passive nanostructure, (2) active nanostructures, (3) nanosystems, and (4) molecular nanosystems. By 2020, the increasing integration of nanoscale science and engineering knowledge of nanosystems promises mass applications of nanotechnology in industry, medicine, and computing and in better comprehension and conservation of nature thereby providing many business opportunities. Nanotechnology's rapid development worldwide is supporting this anticipation of its expected progress of transforming the society and future of business organizations. While studying the business perspective, the essential elements for the successful commercialization of a specifically directed nanotechnology include innovative products, market size, market potential, and the current economic scenario. In this paper, we made a detailed analysis of nanotechnology applications in different fields based on business organizations point of view. Based on the business perspective, a new model of commercialization of nanotechnology products/services is analyzed based on organizational and customer's perspectives. The paper

also contains a detailed discussion on the opportunities and challenges for nanotechnology commercialization as per the developed model in terms of time lag, the valley of death, lack of infrastructure, lack of a standard for evaluation, bureaucratic delays, the dearth of funding, lack of trained professionals, brand image, and public support. Finally, we have discussed the advantages, benefits, constraints, and disadvantages of this new commercialization model in terms of nanotechnology products/services market potential.

2. Nanotech Products & Services:

Various nanotechnology based products and services are entering the market but proper planned strategy of commercialization by companies can create better market demand and hence better return on investment [3-6]. Some of the nanotechnology based products which can help to solve basic problems of the people are:

(1) Products Related to Food and Food Packages:

- ✓ Food processing Nanofilters using nanomaterials.
- ✓ Nanocarrier systems for delivery of nutrients and supplements in the form of liposomes or biopolymer-based nanoencapsulated substance.
- ✓ Inorganic additives such as silver, iron, silica, titanium dioxide, selenium, platinum, calcium, magnesium in nanoformare available for supplements, nutraceuticals, and food and feed applications.
- ✓ A range of ecological finished barrier coating formulations of nanomaterials, used in the production of paper or cardboard destined for packaging with specific barrier requirements.
- ✓ Plastic polymers with nanoclay such as gas barrier, nanosilver, and nanozinc oxide for antimicrobial action, and nanotitanium nitride for strength.
- ✓ Different types of nanomaterial-based coatings are available for food preparation surfaces and for coating food preparation machinery.
- ✓ Nanosensors used to detect pesticides on fruit and vegetables.
- ✓ Nanoparticles encapsulated products are available to deliver vitamins or other nutrients in food and beverages without affecting the taste or appearance.
- ✓ Nanoparticle emulsioned ice-cream which improve the texture and uniformity of the ice-cream.
- ✓ Silver based nano-engineered food packaging provides biodegradable protection against leakage, gas penetration, and pathogen entrance into foods.
- ✓ Carbon dioxide sensor developed based on polyaniline boronic acid conductive polymer nanoparticles for food safety applications including monitoring grain spoilage.
- ✓ Nanotechnology based thermochromic or photochromic inks invented for marketing, brand protection or product safety to include covert tags on labels for smart food packaging.
- ✓ Nanolaminate edible coatings are available to cover food consists of more than one layer.
- ✓ Nanosensors have great potential to hasten the speed of detection, identification and quantification of pathogens, spoilage substances and proteins that cause allergies in food. Nanosensors are usually placed in food packages to monitor the internal and external conditions of the food.
- ✓ Active food packaging using metallic and metallic oxide nanoparticles in nanocompositeate used to improve the shelf-life of foods.

(2) Products Related to Drinking & Potable Water:

- ✓ Portable water filtration products to clean water to produce drinking water.
- ✓ Nano-zero valent iron is used for remediation of groundwater contaminated with chlorinated hydrocarbon fluids and perchlorates.
- ✓ Nanocomposite membranes consisting of nanofillers, is produced as a new group of filtration materials comprising mixed matrix membranes and surface-functionalized membranes.
- ✓ Electro spinning produced nanofibers are used in water and wastewater treatment.
- ✓ Product consists of a combined water treatment process comprising photocatalysis and ceramic membrane filtration, with high capacity of several million cubic meters per day in particular for the degradation of volatile organic compounds.
- ✓ Nanotechnology based sea water desalinator produces drinking water from Sea water using nanotechnology based sea water desalinator.
- ✓ Drinking water from sewage using nanofilters.
- ✓ Nanotech based graphene treatment plant from sewage systems to develop nanotech based graphene treatment plant.

(3) Products Related to Renewable Energy & Storage:

- ✓ Solar-driven photocatalytic hydrogen production using nanotechnology principles.
- ✓ High efficiency electricity generation with metal nanoparticle based dye-sensitized solar cells.
- ✓ Nanomaterial based lithium ion rechargeable batteries for electric energy storage, and solid-state hydrogen storage.
- ✓ TiO_2 and cadmium sulfide based nanostructures show efficient catalysts for water conversion into oxygen and hydrogen for hydrogen fuel cells.

- ✓ Carbon Nanotubes (CNTs), grapheme, and carbon-metal oxide composites are used for long life batteries and electrochemical supercapacitors.
- ✓ Nanomaterial based artificial photosynthesis for production of energy and hydro-carbons.
- ✓ Nanotechnology based photovoltaic cells and organic light emitting devices based on quantum dots as well as carbon nanotubes in composite film coatings are used for solar cells. It can enable cost effective solar and fuel cells with higher efficiency.
- ✓ Silicon-Lead Selenide (Si-PbSe) Quantum dots nanosystem based organic solar cells.
- ✓ Nanostructured high temperature superconductors for low loss power transmission.
- ✓ Nanostructured fillers in component of high voltage power lines for high electrical insulation.
- ✓ Epoxy made of carbon nanotubes used in rotor blades of wind power plants for improved strength of rotor blade parts.
- ✓ Nanomaterial products which acts as better catalyst in production of petrol from Crude oil to improves the efficiency of fuel production.
- ✓ Nanomaterial products based on heat absorbing sensors to converts waste heat in computers, automobiles, homes, power plants, etc., to usable electrical power.
- ✓ Nanocoating as anti-reflection layers on solar cells for increasing the energy yield.

(4) Products Related to Consumer Products & Cosmetics:

About 1,600 consumer products based on nanotechnology are already available in the market [7]. These products are mainly belonging to following categories:

- ✓ Nano-sunscreens to protect the skin from UV rays.
- ✓ Anti-aging skin cream.
- ✓ Hair growth products using liposomes and ethosomes.
- ✓ Hard nanoparticles, such as silicon dioxide, can be used to build up scratch resistant coatings.
- ✓ Nanoparticulate coating for corrosion protection.
- ✓ Nano-coatngs anti-fingerprint coating.
- ✓ Sunscreen made with zinc oxide nanoparticles.
- ✓ Anti-aging skin cream containing proteins enclosed in liposome nanoparticles
- ✓ Skin care creams that delivers nutrients to deeper layers of the skin by using nanoemulsions.
- ✓ Skin care products using nanoemulsions and liposomes.
- ✓ Antibacterial cleaning products using silver nanoparticles.
- ✓ Spray on film containing titanium oxide nanoparticles to kill bacteria and reduces odors.
- ✓ Liquid cleaner using nanoparticles called micelles to remove oils and dirt.
- ✓ Spray on liquid containing nanoparticles which form a hydrophobic film to repel water and dirt.
- ✓ Silver nanoparticles used in household appliances such as clothes, washer, or refrigerator to kill bacteria and to reduce odors.
- ✓ Nanocomposite barrier film to prevent air loss from tennis balls, etc.
- ✓ Tennis racquet frames containing silicon dioxide nanoparticles to increases strength, stability, and power.
- ✓ Epoxy containing carbon nanotubes coating the skin of kayaks to increases abrasion resistance.
- ✓ Resin containing buckyballs (fullerenes) are also used to make badminton raquets to increase power and stability.
- ✓ Ski wax made with nanocomposites to increases gliding performance and maximum speed.
- ✓ Bicycle parts made with carbon nanotubes increases stiffness without weight increase.
- ✓ Fishing rods made with a epoxy resin (called NSi) made with silica nanoparticles to increase the strength without weight increase.
- ✓ Fabric enhanced with nanowhiskers for water and stain resistant.
- ✓ Fabric enhanced with nanopores insulates against heat or chill.
- ✓ Fabric enhanced with some kind of nanoparticles supports dirt rinses off in rain, similar to property of the lotus plant.
- ✓ Fabric enhanced with silver nanoparticles reduces odors.

(5) Products Related to Pharmaceutics & Medicine:

- ✓ Nanosilver dressings to prepare wound healing material.
- ✓ Semiconductor nanocrystals fluorescent biological labels be used as fluorescent probes in biologicalstaining and diagnostics as superior to existingfluorophores.
- ✓ Nanotechnology implants can monitor the body chemistry of patients and trigger drug release at aspecific location inside the body. Biological implants and nanoelectronic devices can be used to enhance sight for the vision impaired and hearing for those who are hard of hearing.
- ✓ Nanoproducts for non-invasive or minimally invasive surgical tools, gene chips and biochemical sensors for early detection and prevention of diseases.
- ✓ Nanotech in regenerative medicine to eventually develop into treatments to replace or repair organs.

- ✓ Nanoparticle based drug delivery.
- ✓ Polymeric micelle nanoparticles to deliver drugs to tumors.
- ✓ Quantum dots for medical imaging.
- ✓ Bucky balls to block inflammation by trapping free radicals
- ✓ Nanoemulsions for nasal delivery to fight viruses (such as the flu and colds) or through the skin to fight bacteria.
- ✓ Nanoparticle cream for delivery of nitric oxide gas to treat infection.
- ✓ Nanoparticles that target tumor cells, when irradiated by x-rays the nanoparticles generate electrons which cause localized destruction of the tumor cells.
- ✓ AuroShell particles (nanoshells) for thermal destruction of cancer tissue.
- ✓ Diagnostic testing using gold nanoparticles to detect low levels of proteins indicating particular diseases.
- ✓ Drugs called nanoviricides developed to attack virus particles.
- ✓ Nanoparticle based synthetic vaccines.
- ✓ Antimicrobial wound dressings using silver nanocrystals.
- ✓ Dendrimer nanoparticles for use in drug delivery.
- ✓ Medical gauze containing aluminosilicate nanoparticles which help blood clot faster in open wounds.
- ✓ Detection of early-stage Alzheimer's disease using Gold nanoparticles.

(6) Products Related to Automobiles & Space Applications:

- ✓ Nanoparticle enforced wheel tires.
- ✓ Nanoengineered thermoplastic materials used in chassis parts to reduce weight.
- ✓ Nanotechnology batteries and fuel cells for electric/ hydrogen powered automobiles.
- ✓ Automobile interiors using dirt-repellent and antimicrobial textiles and surfaces, nanoparticulate air filters anti-glare coatings of mirrors, and instruments made by nanomaterials.
- ✓ Nano-structured coatings in automobile engines.
- ✓ Lightweight, flexible spacesuits using nanomaterials.
- ✓ Nutrient transport between bone tissue and the vascular system using nanotechnology to prevent bone deterioration during the space exploration.
- ✓ Radiation shielding is an area of key importance for space exploration.
- ✓ Anti-glare coatings on automobiles.
- ✓ Automobile bodies using nanosteel to reduce weight.
- ✓ Nano-varnish for stable value and scratch resistance.
- ✓ Nano-filters for clean air in automobile interiors.

(7) Products Related to Industrial Engineering:

- ✓ Nano-cementforimprovement of strength, durability and monitoring.
- ✓ Steel cables can be strengthened using carbon nanotubes for industry applications.
- ✓ Nanoparticle based wood coatings for environmental protection.
- ✓ Nanotech based self-cleaning glasses and heat resistant glasses.
- ✓ Lithography.
- ✓ Integrated chips using miniaturisation of small mechanical moving devices (MEMS).

(8) Products Related to Information Communication & Computation Technology (ICCT):

- ✓ Light emitting diodes and Laser diodes based on nanocrystal quantum dots.
- ✓ Flash memory products.
- ✓ Latest computer hard disk drives & high speed processors.
- ✓ CMOS integrated circuits using sub-22nm geometry.
- ✓ Magnetoresistive Random Access Memory (MRAM).
- ✓ Intel's Integrated circuits with nano-sized features.
- ✓ Computer, mobile phone, and camera displays organic light-emitting diodes, or OLEDs.
- ✓ Conductive inks for printed electronics for RFID/smart cards/smart packaging.
- ✓ Antimicrobial/antibacterial coatings on mouse/keyboard/cell phone casings.

(9) Nanotechnology Services:

Nanotechnology services [8] include:

- ✓ Innovations in displays boards for Advertising using nanotech integrated circuits and light emitting devices.
- ✓ Innovations in security & information storage for banking and financial services using nanotechnology based surveillance and storage devices.
- ✓ Innovation in information collection and storage, Online business in insurance services using nanotechnology supported information communication technology (ICT).
- ✓ Improved product features using high speed and secured technology based on nano devices in retailing services.

- ✓ Increased speed of communication using nanoelectronic devices in tourism business.
- ✓ Nanotech based communication and tracking, online reservation etc. in transportation service.
- ✓ Nanotech based communication, identification and tracking in distribution services.
- ✓ Nanotech based food processing, food packaging, food delivery, clean water supply, reduce, reuse, and recycle waste etc. in hospitality and food services.
- ✓ Nanotech based energy, electronic equipments, entertainment equipments and recreation systems in entertainment and recreation services.
- ✓ Nanotech based communication and storage devices, e-media etc. in mass communication & media services.
- ✓ Nanotechnology based health diagnosis, Health therapy and health information service in healthcare.
- ✓ Nanotech based electronic devices to improve the bandwidth and authentication, electronic documents etc. in Electronic Communication services.
- ✓ Nanotechnology based IT hardware components improves the quality of IT enabled services.
- ✓ Nanotechnology helps to improve online services including education services. Nanotechnology also helps to improve multi-media based education in education services.
- ✓ Nanotechnology based opportunities improves the public utility services related to rainwater, waste and recycling, water and waste water, toxics, community and energy.
- ✓ Nanotechnology improves ICT which improves the quality of services in various real estate and leasing processes in Public Administration services.
- ✓ Nanotechnology based innovations in food processes, water and waste management, energy and health management improves the public administration services.
- ✓ The various resources used in defence services are improved in terms of their quality using nanotechnology in defence services.
- ✓ Nanotechnology based control of greenhouse gases emission improves the quality of various business support services.
- ✓ Nanotechnology supported marketing concepts based on reducing, recycling and re-using resources improves the benefits of marketing services.
- ✓ Since nanotechnology is going to be general purpose technology, the quality of many professional services can be improved by using nanotech based innovations.
- ✓ Nanotechnology based environmental sustainability and decreasing environmental degradation improves the quality of social services in the society.

3. Nanotechnology Commercialization:

Technology commercialization is the process of converting ideas into products for businesses and consequentially, creating demands for the products and jobs for the people. Commercialization of nanotechnology from research to economically viable product is particularly vulnerable to the "Valley of Death" point of commercialisation graph compared to any other technologies due to the reasons related to a product focus, market engagement, scale up and product development [9].

3.1 New Model of Nanotechnology Commercialization:

From a business perspective, the essential elements for the successful commercialization of a specifically directed nanotechnology include innovative products, market size, market potential, and the current economic scenario and accordingly using qualitative data collection instrument namely focus group method [10-15], we have developed a model for successful nanotechnology commercialization process as shown in fig. 1 which include ten steps to develop standard products/services.

Steps in Nanotechnology Commercialization Model:

- ✓ Identification of Problems in the society : When an organization is planning to encash opportunities in nanotechnology-based business, it has to carry out a market survey and has to arrive at the conclusion on which product in which area has better demand, easy to develop, produce and market with low initial investment and sustainability.
- ✓ Finding technological solutions through Ideas & Concepts: After identifying the possible products based on nanotechnology, the firm should do a technological feasibility study of producing such product with requited features.
- ✓ Research & Invention – Product development, design, modelling & simulation: Once the firm understands that identified product is feasible to develop, it has to invest in indigenous research or collaborate with existing research organizations to develop the product.
- ✓ Disclosure of Invention: Soon after the product is developed in R & D section of the firm, enough publicity should be given through various types of campaigns to create local and global demand.
- ✓ Assessment of invention: Parallelly, the firm should make an assessment on the features of the products, reproducibility of the properties, reliability on the performance etc.
- ✓ Patenting: In order to protect the intellectual property right of the invention, the firm should get protection by applying for patent on the product/processes.

- ✓ Licensing: Based on the patent right, the firm has to plan its strategy and take the decision to produce the product either directly under its own brand or by licensing to other firms spread globally.
- ✓ Revenue generation: Through creating demand as well as its pricing strategy the firm has to decide its revenue generation model to realize its objective of maintaining long term profit.
- ✓ Up gradation based on environmental scanning: Based on feedback from the stakeholders, and monitoring its environmental effects, the firm has to continuously upgrade the performance of the product and monitor its quality & performance.
- ✓ Standard product / services: By standardizing the product/service, the firm can implement and develop technical standards which help to maximize compatibility, interoperability, repeatability, safety, or quality. It can also facilitate commoditization of the product.

Any firm which plans to do business using nanotechnology products/services get success by following the above steps of our nanotechnology commercialization model.

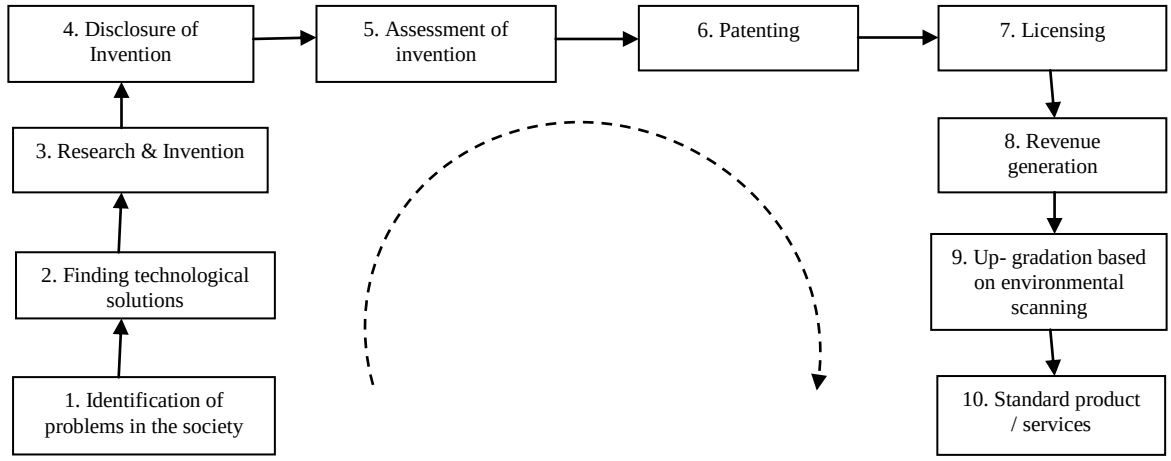

Figure 1: Steps required in successful nanotechnology commercialization model [16].

3.2 Opportunities for Nanotechnology Commercialisation:

- ✓ Huge expectation from the society: By knowing the advantages and benefits of nanotechnology, people are waiting for the breakthrough of nanotechnology products in all areas of the consumer requirements in the society.
- ✓ Opportunity for new innovative product development: Based on substantial advantages and hence expected huge demand for nanotech products, there are almost infinite number of opportunities for new product development in different areas of the society.
- ✓ Opportunity for both small business and mega business players based on their investment capacity: Since nanotechnology products varying from simple cosmetic product to screen infrared rays from skin to artificial food products to self-generating molecular motors, depending on the interest and capability of firm, it can focus a particular type of product so that both small business firms and mega business firms have opportunity in nanotechnology product development and marketing.
- ✓ Opportunity for new product development for entrepreneurs in their existing field itself so that they can use their experience: Being general purpose technology, nanotechnology provides scope for existing firms to upgrade their products/services. Hence, the existing entrepreneurs can plan to improve their products by improving them using nanotechnology features for improved performance.
- ✓ The new discoveries and innovations get patent protection to commercialize their inventions. So that the investment of the firms will not be wasted due to their right to get patent protection for their inventions.
- ✓ The new technology gives an opportunity to explore new business and sustainable earnings through the use of systematic commercialisation process.

3.3 Challenges for Nanotechnology Commercialization as per New Model:

New inventions based on new technology, usually attract attention due to their ingenuity, but a product must also be useful and compelling, enabling it to be used in everyday life. The objective of the firm is to identify a market for its new products [17]. From a business perspective, the steps to be followed for the successful commercialization of a nanotechnology based product include market size, market potential, and the economic scenario of the countries and the people who use such products [18]. Common challenges faced by nanotechnology firms are:

- ✓ Time Lag: The average time delay between research, completion, and commercialization of a nanotechnology product can lie between three to five years [19-20]. The banks and other financial

funding agencies, find this time lag to be a major detriment due to the fact of the block of their capital [21].

- ✓ Valley of Death: This is the gap between a positive scientific result of a researcher and obtaining supporting funds for commercialization and prototyping of the product [21]. Since the cost of commercialization is very high compared to the invention cost of the product, usually, the scientist who invented the product may not have the interest in commercialization, but the firms invested for such research have to spend to encash its business opportunity.
- ✓ Lack of infrastructure: Nanotechnology product based research is expensive and requires costly instruments. The lack of infrastructure retards the progress of new product invention.
- ✓ Lack of standard for evaluation: A major obstacle for developing nano-products is the lack of standards for evaluation of performance at different stages of research. Because of this, normalizing standards by which nanotechnologies can be evaluated are lacking which affects the patenting process.
- ✓ Bureaucratic delays: Patent policies take up to thirty-six months to respond to a single application, a serious problem when even a slight delay can be detrimental. Due to lack of a coherent policy on technology transfer from universities to start-up businesses and a considerable red tape must be dealt with for any such transfer using black ocean strategy [22-23].
- ✓ Dearth of funding: Since the research in nanotechnology is capital intensive due to the state-of-the-art instruments requirement, firms faces challenges in obtaining funding. Thus, commercialization of nanotechnology products requires huge investments which small to medium firms cannot be secure easily.
- ✓ Lack of trained professionals: The lack of sufficiently trained scientists, engineers, technicians, and researchers in the field is another barrier [21]. This is mostly due to lack of addition of nanoscience and technology in the engineering and science syllabus.
- ✓ Pseudo Environmentalist: The speculation in environmental, health and safety issues of nanotechnology-based products, there is much debate about effects of nanotechnology might have on surroundings. Pseudo-environmentalists take this as an opportunity for fighting against the technology and do negative publicity to pressurize the firms to demand ransom.
- ✓ Public support: Public support is always favourable due to their expectation towards any emerging technology, including nanotechnology. As a result, firms who invest in new technology to provide better high-tech products to them gets a higher brand image and public sentiments in their favour but small firms and start-ups that currently constitute a major chunk of nanotechnology product firms do not have such advantage [24-28].
- ✓ Sustainability in the market: The final challenge for the firms is maintaining the sustainability for the commercialized product or service for longer time to get the return on investment and expected profits through planning and executing proper marketing strategy [28].

4. ABCD Analysis of New Model:

This new commercialization model inspires the organizations to involve and invest on nanotechnology-based research by identifying the opportunities to solve issues related to both basic problems and problems on the comfortable life for human beings in the society. The identified opportunities have to be encashed by these interested organizations by setting their objectives to find technological solutions through investment on research and development. The results of their research and innovations are to be tested in the laboratory before commercialization of inventions. To protect the intellectual property right of the invention, the firms initially go for applying the patent for their products/processes. After obtaining the patent, the firms decide on producing the products and try to create a global market and selling them to the global market based on demand either starting their own subsidiaries or by licensing other firms to produce these products in standard form. This commercialization model allows the firms to generate revenue and hence profit. Thus, a firm can get a return on investment with profit for solving the social problems on both basic and comfortability issues by following above commercialization model. This commercialization model has following advantages, benefits, constraints, and disadvantages [29-35].

4.1 Advantages:

- ✓ Investment on research based on possible demand for new technology due to its ability to solve both basic problems in the society and problems related to comfortability of life.
- ✓ Companies get a new idea and opportunity to expand their business.
- ✓ New product development which has high demand universally.
- ✓ Patenting opportunity to protect intellectual property right of the invention.
- ✓ Licensing opportunity to get a return on investment.
- ✓ New products with multi-features, low price, and optimum performance.
- ✓ Nanotech products have long durability.
- ✓ Involvement of company in new product development through prototyping and then standardization.

- ✓ Commercialization of nanotechnology products is given priority and supported by many developed countries for the advancement of civilization.

4.2 Benefits:

- ✓ Products developed based on society need and hence huge demand.
- ✓ Commercialization of indigenously developed product/service gives an opportunity for sustainable profit.
- ✓ Monopoly and global business opportunity through the patent.
- ✓ Opportunity to improve product features through innovation after prototyping till standardization.
- ✓ Organizational sustainability in competitive and uncertain business environment.
- ✓ New brand creation or brand stabilization in new technology area through innovative nanotech products.
- ✓ Mass production or licensed production leads to global business and global marketing which in turn gives better profit.
- ✓ The society gets the benefit of using advanced products at affordable price and hence support for the advancement of civilization.
- ✓ Government subsidy and tax benefits for research and commercialization of nanotechnology products & services.

4.3 Constraints:

- ✓ Investment in research & development for new product/service invention.
- ✓ Breakthrough in research for new sustainable and useful product.
- ✓ Involving innovative & creative scientists by hiring them.
- ✓ Protecting the intellectual property right of the invention through patenting.
- ✓ Market size, market potential for the invented product and the economic scenario of the countries and the people who are prospective customers.
- ✓ Educating the people to use nanotech products and on safety issues.
- ✓ Standardization of the product/service for global acceptance.
- ✓ Identifying competitive firm for licensing.
- ✓ Lack of Government supports in many countries due to the fear of unknown environmental degradation and side effects of these products.

4.4 Disadvantages:

- ✓ Huge initial investment for developing an innovative product based on a survey on demand in the society.
- ✓ The risk in investment on research & development in nanotechnology due to possible failure on inventing breakthrough products/services.
- ✓ Speculation in environmental, health, and safety issues of nanotechnology-based products usage.
- ✓ Commercialization of the product may need further standardization.
- ✓ The possibility of licensing firm's involvement in unethical practices which affects the profit and the brand name of the parent firm.
- ✓ Any delay in any stage of product/service commercialization facilitates the competitors to overtake.

5. Conclusion:

Our analysis based on research results and publications, it is understood that nanotechnology is going to be the general purpose technology to support and solve major problems of the human beings and the society due to its potential ability to find amicable solutions at micro-level and expanding it to macro-level. It is found that nanotechnology commercialization is lagging behind due to many reasons and hence failed to follow the expected generations in its growth stages. But as per new predictions, nanotechnology is developing to solve almost all problems of human life by 2050 by reaching the stage of singularity in which growth rate in NT applications become infinite. In this paper, we made a detailed analysis nanotechnology applications in different fields based on business organizations point of view. Based on the business perspective, we have developed a new model nanotechnology products/services commercialization model and analyzed it based on organizational and customer's perspectives. The paper also contains a detailed discussion on the opportunities and challenges for nanotechnology commercialization. In terms of time lag, the valley of death, lack of infrastructure, lack of a standard for evaluation, bureaucratic delays, the dearth of funding, and lack of trained professionals, brand image, and public support. Finally, we have discussed the advantages, benefits, constraints, and disadvantages of this new commercialization model in terms of nanotechnology products market potential.

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