Solar Cold Chain Optimization Research – An Integrated Multidisciplinary Project Agenda

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ABSTRACT

Cold supply chain facilities are essential to the producers and suppliers of perishable commodities especially for farmers and fisheries to protect their agricultural and fish products for a long period during transportation from origin to destination. The traditional 'Solution' has been put in place for small Cold Storage facilities connected to the Grid or running from Diesel Generators – these though are dependent on stable electricity and in the case of Diesel powered it is expensive to maintain and run and have an environmental impact. Solar Powered Cold Chain through combined developments in battery technology, can provide uninterrupted Cold Storage and Cold Chain solutions that are economic to operate, environmentally friendly, and able to be located in rural places where electricity supplies cannot be relied on. It is observed that there is a research gap in practical and applied research in the area of fully integrated Solar Cold Chains. The research proposal highlights the opportunities associated with Solar Powered Cold Chain, particularly the positive economic impact that can deliver to the actual farmers and fishermen that grow and catch foodstuffs – enabling larger amounts of income to be earned and retained in the rural economies. The research provides the idea of adopting and managing Solar Cold Chain facilities for perishable commodities like farming and fisheries in developing countries through its systematic analysis using ABCD framework.

Keywords: Cold chain, Solar cold chain, Farming and Fisheries in Developing Countries, Environmental friendly solutions.

1. INTRODUCTION :

A cold chain or cold supply chain is a complete system for the perishable commodities including food items, which handles the movement of the commodities uninterruptedly within a low temperature environment during the postharvest steps of the value chain including harvesting, collection, separation, processing, packing, storage, transportation and marketing until it reaches the final consumer. Thus, it is a lifecycle of a commodity movement from harvesting to end users in a quality protective environment usually optimum low temperature. Cold chain facilities are essential to formers and fisheries to protecting the quality of their agricultural and fish products for a long period while transporting them from the source of collection to market destination.

An integrated cold chain system for food items encompasses the integrated management of the movement of perishable food products from the field, ranch, or body of water through the entire postharvest chain to the final consumer in a temperature protective environment. Such integrated management requires strategies to handle perishable products throughout the supply chain and requires improvements in terms of cost and optimum utilization of various resources used for the purpose. Such improvement requires integrated research to improve the cold chain processes in terms of using various resources including the time of movement of perishable products from source to destination. Thus, the three variables associated

with the cold supply chain cycle for a particular product include cost, time, and temperature and through strategically planned research these variables can be optimized.

The traditional cold chain makes use of small Cold Storage facilities connected to the Grid or running from Diesel Generators – these though are dependent on stable electricity and in the case of Diesel powered it is expensive to maintain and run and have an environmental impact. On the other hand, an ideal Cold supply chain uses renewable energy and for such a system, the values of deterministic variables (cost, time, and temperature) are set to zero and have zero impact on the environment (table1) [1]. The ideal cold supply chain can be realized using two innovative models.

(1) In the first model, using certain additive, the optimum preserving temperature should be maintained at room temperature. For example, by adding some preservatives, if the given fish product preserving temperature is maintained at an environmental temperature of that region, then the cold chain to maintain a low temperature to the fish product is not required and the problem of quality maintenance of the fish product can be solved. This model suggests to discover a new innovative low cost preservative material which should not have any negative effect on quality and taste of the food for consumers but able to raise the preserving temperature of the food products or any perishable products to transporting environmental temperature. Even though it is a crazy idea, this line of research may lead to an optimum solution close to the ideal solution provided the preservative material is nontoxic, non-odour, having no side-effects and made by abundantly available low cost material.

(2) In the second model, a proper package (static box or movable vehicle) should be developed which keeps the temperature of food item to an optimum level to maintain the consumable quality at destination however far maybe. This model needs an integrated cold chain system with an objective to maintain a required low temperature box to hold the perishable product at a temperature at or below optimum freezing temperature throughout the journey from starting location (production point) to the destination (consuming point). Such a cold chain system should ideally have characteristics shown in table 1 [2-3]. Though ideal systems are hypothetical systems and cannot be realized in practice, they give ideas on how to improve the qualities and characteristics of practical systems towards the ideal system. The gap between the practical system characteristics and the ideal system characteristics is the opportunity for researchers to improve system performance through their research contribution [4].

Table 1: Characteristics of an Ideal cold supply chain (Hypothetical)

S.No.	Cold Chain Characteristics	Values
1	Cost	Zero
2	Time of development	Zero
3	Energy	Zero/renewable
4	Temperature	Constant at desired level
5	Efficiency	100%
6	Weight & Size	Zero and flexible
7	Availability	At zero time
8	Use of physical resources	Zero
9	Time of usage of product	Infinite
10	Transportation Time	Zero

Solar Powered Cold Chain though is coming to the force, combined with developments in battery technology, this can provide uninterrupted Cold Storage and Cold Chain solutions that are economic to operate, environmentally friendly, and able to be located in rural places where electricity supplies cannot be relied on. It is observed that there is a gap in practical and applied research in the area of fully integrated Solar Cold Chains. In this proposal, we have suggested how cold supply chain for perishable products can be optimized by utilising efficient solar energy systems, effective freezer technology, suitable packaging system, optimum planning and controlling perishable temperatures, efficient managing of solar systems for freezer controls, optimizing supply chain through ICCT universal technology, the economics, and social implications. The various research agendas for a complete supply chain cycle of activities from the production side to the consumer side are proposed systematically for possible integration and collaboration of experts from different areas of science, technology, management, economics, and social science.

2. CHALLENGES IN COLD CHAIN SYSTEM :

There are many technical, logistical, and investment challenges as well as economic opportunities related to the use of the cold chain.
The primary segments of an integrated cold chain include :
(1) Packing and cooling fresh food products,
(2) Food processing (i.e. freezing of certain processed foods),
(3) Cold storage (short or long term warehousing of chilled or frozen foods),
(4) Distribution (cold transport and temporary warehousing under temperature controlled conditions),
(5) Marketing (refrigerated or freezer storage and displays at wholesale markets, retail markets and foodservice operations),
(6) Economical & Social development of people involved in this business of production, distribution and usage.
Research in Cold supply chain for perishable commodities is a Multi-disciplinary area and involves experts and policy makers from various fields including the agriculture, energy, education, and food sectors must work together to promote the use of :
(1) Cold chain technology,
(2) Improve logistics, maintenance, services, infrastructure, education, and management skills, and
(3) Create sustainable markets for the design, use and funding of cold chains for reducing perishable food losses.

3. RELATED RESEARCH WORK :

Being a basic necessity and grown or harvested from distance locations for large scale consumption like cities and towns, various food items have to be transported safely without deuteriation in quality. Global food losses have been documented to be on the order of 25% to 50% of production volumes, caloric content and/or market values in the supply chain depending on the commodity (Lipinski et al, 2013; Gustavsson et al 2011) [5-6].

Table 2 : Some of the published scholarly papers related to cold supply chain

S.No.	Area of Research	Focus of Research	Reference
1	Supply chain	Fish products	Islam, S. B., (2013)[7]
2	Supply chain	Rural to Global food management	Viswanadham, N. (2006) [8]
3	Supply chain	RFID-enabled traceability system for fish products	Hsu, Y. C. et al. (2008) [9]
4	Supply chain	Quality in competitive fresh food products	Besik, D., et al. (2017) [10]
5	Supply chain	Need for paradigm shift in supply chain management of fruits & vegetables in India	Halder, P., et al. (2011) [11]
6	Cold Supply chain in different countries	A weak link in the fruits and vegetables in India	Negi, S., et al. (2015) [12]
7	Cold Supply chain in different countries	Study on current status of cold chain in China	Zhao, H., et al. (2018) [13]
8	Cold Supply chain in different countries	Calculation of future demand in South Korea	Son, C. H. (2012). [14]
9	Cold Supply chain in different countries	Seafood safety and quality in supply chain in Oman	Al-Busaidi, M. A., (2016) [15]
10	Cold Supply chain in different countries	Management for Perishable Food in India	Rathore, J. (2013). [16]
11	Cold Supply chain in different countries	For reducing food losses in developing countries	Kitinoja, L. (2013). [17]
12	Cold Supply chain	Food chain and climate change	James, S. J., et al. (2010) [18]

8	Technology use in Cold Supply chain	Comparison between chilling and superchilling technologies	Hoang, H. M., et al. [19]
9	Technology use in Cold Supply chain	Decision-making using data analytics	Chaudhuri, A., [2018] [20]
10	Technology use in Cold Supply chain	Energy-smart technologies for cold chain	Sims, R., et al. (2015) [21]
11	Technology use in Cold Supply chain	Wireless multi-gas-sensors system for cold chain	Wang, X., et al. (2017) [22]
12	Technology use in Cold Supply chain	Internet of Things (IoT)-based risk monitoring cold chain system	Tsang, Y. P., et al (2018) [23]
13	Technology use in Cold Supply chain	Food chain safety based on HACCP, blockchain & Internet of things	Tian, F. (2017). [24]
14	Management, economics and Social status	Containerization of commodities and the cold chain	Rodrigue, J. P., et al. (2015) [25]
15	Management, economics and Social status	Time–temperature management	Mercier, S., et al. (2017) [26]
16	Management, economics and Social status	Fish vendors and market performance of whole sell fish market in a district of India	Verma, H. O., et al. (2015) [27]
17	Management, economics and Social status	Structural performance of fish market in a district of India	Upadhyay, A. D., et al. (2016) [28]

4. OBJECTIVES OF PRESENT RESEARCH PROPOSAL PLAN:

This project proposal identifies opportunities and challenges to start an Advanced Research Centre on an Efficient Solar Cold Chain Development & Implementation by means of Integrated Research in Multidisciplinary areas including :

(1) Material Science Research for improving the efficiency of Solar Cell Systems & Battery Storage systems.

(2) Engineering Research for Developing the Improved Solar powered Refrigeration for small, medium and large container based systems.

(3) Food and other perishable products Research for quality maintenance & Packaging.

(4) Supply chain Research for developing an integrated and efficient logistics for transportation of food commodities from Source to Destination.

(5) To visualize & develop New or Improved Networking Models using IOT & Other ICCT Technologies.

(6) Proposing a Commercialization plan for developed Technology.

(7) Studying the investment patterns & economic impact of the outcome.

(8) Analysing the need, social impact & Empowerment in developing countries.

5. METHODOLOGY & RESEARCH STRATEGY :

The methodology of this solar cold supply chain research project proposal development include:

(1) Studying the logistics and supply chain perishable products from origin to destination.

(2) Identifying Sub Areas of the supply chain cycle.

(3) Developing a Review Papers, studying the present status, imagining future solutions, identifying Gap between present status and future requirement, &developing Research Agendas in each Sub Area.

(4) Developing Research Objectives in each Sub Area.

(5) Using Research Scholars/ Research faculty of the University for further Research in each Area.

(6) Organizing a Conference/ Workshop in Cold Chain & Related Area to exchange ideas.

(7) Development of Research Proposal in each sub area.

(8) Integrating the Research proposals for External Funding.

6. CURRENT COLD STORAGE AND COLD CHAIN SOLUTIONS IN DEVELOPING COUNTRIES :

An integrated cold supply chain is a cyclic operation in which any perishable product should be protected as fresh while transporting it from the origin of production to the destination of consumption. The transportation of such goods may take any amount of time depending on the distance between the origin and destination. Various types of cold storage equipment from small cold storage boxes to big cold storage containers are used for transportation which keeps the perishable materials to be fresh and usable quality. In the process of packing and transportation of such perishable products, cooling and freezing are essential to maintain the quality which adds to the cost. In developing countries, the majority of people involved in occupations like seafood, agriculture, farming, dairying, plantations of flowers, etc can sell their products to the market by using suitable cold chain systems. If a suitable cold supply chain system is available at low procuring and maintaining cost, good percentage of produced perishable products can reach the market and earnings of the people and the economy of the country will get benefits.

Cold supply chain logistics involves transition between the six segments including: (1) Production, (2) Processing and packing, (3) Preserving, (4) Transportation to various destinations, (5) Distribution to retailing shops, and (6) Reaching end users. The cold supply chain should maintain optimum temperature to preserve the quality and safety of the food to avoid wastage of perishable products in an economical manner. The objective of such a cold supply chain system id to decrease the cost by using suitable technologies and renewable resources at all six segments of the cycle. The speed of transportation to the identified destination by maintaining freezing temperature is the primary factor in the cold supply chain. The cost and speed of cold supply chain are primary factors in developing countries and the food producing people are suffering due to non-availability of such an optimum supply chain. Use of renewable energy resources to an optimum extent allows the researchers to reduce the cost and use of information communication and computation technology (ICCT) [29-33] and transportation technology allows to optimize the speed so that the complexity of cold supply chain for perishable products in developing countries can be solved to the satisfactory level.

Presently, in developing countries, various cooling systems like radiant cooling, passive cooling based on the insulating box, or oil based electric generator systems are currently used for cooling or freezing the food products. Since many cases the freezing temperature requirement is up to -40^{o} C for a long time until the product moves in the cold supply chain to reach its destination of consumption. Research opportunities for developing effective renewable energy sources for cold chain refrigerators, research on low cost high efficient scalable refrigerator technology, research on identifying optimum non-perishable temperature to various products in the cold supply chain, research on the use of optimum communication and computation technology to identify high demand markets throughout the world, research on using and monitoring suitable logistics and supply chain system to enhance the speed of transportation, research on the quality of perishable products for consumption at the destination, Study and analysis of economic aspects of the system and the stakeholders and the social impact on the living status of the people involved in production and supply of perishable products business are open in developing countries to improve the quality of life in the society.

7. SOLAR POWERED COLD CHAIN STORAGE :

Solar energy is abundant and renewable in many developing countries and is available free of cost in any even remote region during day time. The cost of solar panels is continuously decreasing with increased efficiency and durability but not reached an appreciable level. Solar energy can be used only in the day time and hence a suitable battery technology to support cold storage systems of the cold supply chain of perishable products from origin to destination.

7.1 Current Status of Solar TechnologyResearch :

(1) Si-based heterojunction solar cells :

Also called Perovskite solar cells shows 20–30% conversion efficiency [34] and are used in solar panels installation. Multi crystalline modules and monocrystalline modules are presently available in markets.

(2) Dye-sensitized solar cells :

DSSCs technology provides about 15% conversion efficiency but is attractive for further research due to its low cost, simple preparation methodology, low toxicity and ease of production [35].

(3) Quantum dot solar cell technology:
In this type of solar cells, quantum dots of variable size are used as photovoltaic absorbing material. These dots replace bulk semiconductor material commonly used in heterojunction solar cells. The bandgap of quantum dots istuneable across wide energy levels by varying their size. Quantum dots promise low cost solar cells but presently of comparatively lower efficiency [36], [37].
(4) Plastic solar cell technology :
Plastic solar cells use nanotechnology based polymer material and even capable to convert invisible infrared rays of Sun into electrical energy. Such solar cells can functional during 24 hours round the day. Various teams are researching in this area to enhance plastic solar cells efficiency to a reliable level [38-41].
(5) CIGS thin film solar cell technology :
Copper-Indium-Gallium-Selenide is a thin film heterojunction solar cell with the flexibility to vary bandgap to absorb a range of energy wavelengths of solar energy. CIGS is a direct bandgap material capable to absorb the sunlight completely at 1-2 micrometre thickness [42-44].

7.2 Present Status of Electricity Storage:

The electrical energy produced by renewable or non-renewable sources has to be stored properly for anytime utilization in a portable system. Various electrical energy storage technologies are currently in use.
(1) Lead Acid Batteries :
This is the most widely used rechargeable battery with cathode is made up of PbO_2, the anode is made up of Pb, and the electrolyte is made up of Sulfuric acid. These batteries have fast response time and small self-discharge rates with low device cast. The research issues include (1) material research for performance improvement, (2) use of the battery technology in applications like the wind, (3) photovoltaic power integration, and (4) automotive renewable energy sectors [45].
(2) Li-Ion Batteries :
This has a higher unit voltage than lead-acid batteries, with cathode is made up of lithium metal oxide, anode is made up of graphitic carbon, and the electrolyte is normally a non-aqueous organic liquid containing lithium salt $LiClO_4$. These batteries have good response time and a small dimension. The research issues include (1) to increase the power capacity of the battery by using nanotechnology, (2) to enhance specific energy of the battery by inventing advanced electrode materials and electrolytic solutions [45, 46].
(3) Sodium-Sulphur Batteries :
This is another potential electricity storage system with sodium and molten sulphur as two electrodes with beta alumina as a solid electrolyte. The constraint of this system is that it needs a high operating temperature of 574 to 624 K. This battery system is attractive due to low cost and non-toxic materials usage leading to high recyclability. The research agenda includes(1) how to reduce operating temperature by identifying an alternate electrolyte that can work at room temperature, (2) Enhancing the cell performance indices and unit voltage storage capability [45, 47].

Table 3 : Research agenda in some of commonly used battery systems [45,46,47]

S. No.	Battery System	Unit Voltage	Research agendas/Issues
1	Lead Acid Batteries	2.0 V	(1) Material research for performance improvement including unit voltage and electrolyte degradation (2) Use of the battery technology in applications like the wind (3) Photovoltaic power integration (4) Automotive renewable energy sector
2	Li-Ion Batteries	3.7 V	(1) To increase the power capacity of the battery by using nanotechnology (2) To enhance the specific energy of the battery by inventing advanced electrode materials and electrolytic solutions
3	Sodium-Sulphur Batteries	2.08 V	(1) How to reduce operating temperature by identifying an alternate electrolyte that can work at

			room temperature (2) Enhancing the cell performance indices and unit voltage storage capability by using nanotechnology

8. RESEARCH OPPORTUNITIES FOR VARIOUS DIVISIONS :

The solar cold supply chain research project is a teamwork based combined effort of researchers of several divisions including basic science, material science, engineering, nanotechnology, food processing & packaging technology, refrigeration & thermal engineering, logistics and supply chain management, transportation technology, information communication & computation technology, management & economics, and social science. The various opportunities for such experts include :

(1) Scientific Research on Improving Solar Cell Efficiency & Battery Storage (Materials Research).

(2) Technological Research on Developing the Improved Solar powered Refrigerators (Electrical & Mechanical Engineering Research).

(3) Developing/Improving Supply chain Models from Source to Destination (Supply Chain Management).

(4) New or Improved Networking Models using IOT & Other ICCT Technologies (Electronic & Computer Science Research).

(5) Food Preservation & Quality Maintenance Research (Hotel & Food Management Research)

(6) Commercialization of Solar Cold Chain Devices & Systems (Applied Research).

(7) Investment Challenges & Economic Opportunities (Management & Economics Research)

(8) Social Impact & Empowerment (Social Science Research)

8.1 Solar Cell Efficiency Enhancement :

Photovoltaic cells also called solar cells are devices to convert photon energy into electrical energy. Many cells are fixed in series to form solar panels. The usefulness of solar energy as renewable energy depending on the efficiency of conversion into electrical energy and the ability to use it instantaneously or after storage using a suitable battery system. As mentioned previously, present solar cells available in the market have maximum efficiency close to 20%. So, there is an opportunity to increase the efficiency of conversion of these cells another 80% through intensive research. Such an effort will also help to cater to a huge amount of renewable energy requirements for other purposes. By increasing conversion efficiency and decreasing the cost of solar energy, it can be made a popular renewable source of energy [48,49,50]. The researchers are working on two areas to improve the efficiency of solar cells.

[1] Internal method: In this method, the type of materials used, design of solar cells, and the setup models of usage are continuously varied to improve the internal efficiency of the cells. Most of the research work in solar systems focused on the internal method of improving the efficiency of conversion. Semiconductors and nanocomposites are providing hope in this regard.

(2) External method: In this method, the efficiency of solar cells is improved by coating polymer or nanolayer on the top of the solar cells. The principle behind this may be to focus the solar energy or to avoid loss during the conversion process. Unlike the internal method, a small amount of efficiency variation is only possible in the external method.

8.2 Electric Storage Efficiency Enhancement :

(1) Storage Battery System: Intense research is on to increase the storage efficiency of batteries. Research work is continued in lead-acid, Li-ion, Li-metal, Li-polymer, Na-ion batteries and on different combinations of nanomaterials [51].

(2) Supercapacitors: Supercapacitors, also called ultracapacitors allow to store huge electrical energy for a longer period with some limitations. It is expected that intensive research in the supercapacitor field leads to the end of conventional batteries as a storage system for electricity [52].

8.3 Refrigerator Research :

(1) Refrigerator Technology :

A refrigerator is a device made by a thermally insulated compartment and a heat pump that transfers heat from the internal side to the external side using a process called cooling. It is an essential food storage system in developed countries and if improved in terms of efficiency, cost, and mobility, will be useful even in developing countries. To get the true advantage of refrigeration technology in food and other perishable products preservation for a considerable amount of time during transportation, the major

requirements are (1) It should use simple, (2) low cost, (3) powered by renewable energy, (4) mobility to harvesting locations, (5) optimizing refrigeration temperature & time, and (6) scalability.

(2) Refrigerator Size :

The variability of the size of the refrigerator and the duration of maintenance of freezing temperature are two key factors along with optimum refrigerator technology. The available size of the refrigerators should support preservation and transportation for small scale business, medium scale business, and large-scale business.

(3) Green Refrigeration :

Renewable low power assisted portable refrigerators are finding importance in rural and remote places for large scale usage. Solar powered battery assisted refrigerators are best suitable as green refrigerators for cold chain systems due to their environmental friendliness [53].

8.4 Research on optimum food freezing temperature and control for quality food :

(1) Effect of freezing on food Quality:

Freezing is a convenient way to preserve food and other perishable commodities during transportation from origin to destination. Research on various effects including :(i) Chemical physical changes during freezing leading change in size, weight, colour, odour, taste, flavour, nutrients, and enzymes; (ii) Textural changes due to loss of water content leading to degradation and spoilage.(iii) Study on the rate of freezing and duration of freezing on food quality, etc.

(2) Optimum freezing temperature research for perishable commodities :

Research on identifying optimum freezing temperatures for different types ofperishable commoditiesin different environments and geographical locations is very important in deciding the type and nature of refrigeration to be used [54].

(3) Changes in quality and freshness caused by fluctuating temperature :

A systematic study is also required in different countries as a part of cold chain research to investigate the changes in the quality and freshness of different perishable commodities with fluctuation from freezing temperature as well as the stability of different types of refrigerator device.

(4) Other Aspects :

Other aspects like freezer burn due to moisture loss from the surface area of the products, microbial growth in the freezer, and its effect on preserving duration, quality of food, etc.

8.5Transportation & Supply Chain Research using Renewable Energy :

(1) Renewable energy for transportation :

Solar energy and bio-fuel energy are used in a variety of transportation systems either onboard using direct sun or off-board using battery technology to take care of the environment. Renewable energy assisted transportation systems in rural and remote areas are the boon for the formers or fishermen in developing countries provided, such systems are useful with expected efficiency and affordability.

(2) Renewable energy for cold storage :

Solar powered (online) or solar battery powered cold storage (offline) using innovative refrigeration technology is an essential part of a complete cold supply chain cycle. Automated, easy to operate cold storage/refrigeration system which is powered by renewable energy systems are attractive for common man usage. Research is due in the area of developing efficient solar cells with close to 100 percent efficiency.

8.6 Improved Networking Models using IOT & Other ICCT Technologies :

(1) Identifying the right location based on immediate demand using IoT :

Internet of Things (IoT), being premier underlying technology of Information Communication and Computation Technology (ICCT) which is considered as Universal Technology of 21st century [29-33]. IoT also provides communication and sensor support in Industry 4.0 and hence considered as the backbone of Industry 4.0. The logistics and supply chain management systems get support for innovations in accurate and timely delivery of various perishable commodities from origin to destinations by adopting IoT based supports at various stages of the chains. IoT provides an opportunity to build smart, secure, and efficient supply chain systems [55]. Research is continued in the field of application of IoT in the solar cold chain system [56]. Efforts are going on to find an integrated solution for solar cold chain portfolio management using IoT [57-58].

(2) Identifying the right package for delivery using Blockchain technology :

Blockchain technology, another underlying technology of ICCT [59-61], being traceability, safety, and

secured identification technology, can be used for secured transportation and delivery to the right place [59-61].

8.7 Food Preservation & Quality Maintenance Research :

Research is also due in many areas in food and other perishable commodities supply chain including the stocking at origin and warehouses till it reaches the consumers. Studies on food preservation and quality packaging for a long time in a different environment (natural and artificial) are essential and interesting. Such research may lead to better management of the food supply chain leading to minimized wastage. Systematic research on the effect of nanotechnology based innovations and inert gas usage while packaging of perishable products to preserve them for a longer period and at low expenditure is still essential for developing countries. Some of the major research topics include :

(1) Use of antimicrobials in food packaging and quality study [62].
(2) Use of high frequency light and sound on perishable items during packing [63].
(3) Food preservation by using hurdle technology [64].
(4) Development and study on various non-thermal food preservation technologies and their suitability to various environments, [65].
(5) Use of innovative nanosystems in food preservation and packing systems [66], etc.

8.8 Research on Commercialization of Solar Cold Chain Devices &Systems :

Commercialization of technology based inventions are the final step in any research project. There are many steps in commercialization models including, problem identification, finding technological solutions, Analysing each solution in detail by considering its feasibility, choosing optimum solution within the constraints, disclosure of innovation for critical comments, assessment of solution for practical feasibility, patenting for an intellectual property right, licensing, revenue generation, upgradation based on environmental scanning and finally standardization [67-68]. These steps called phases of commercialization are essential in every systematic invention and in cold chain research also these phases play an important role. Solar cold chain research is a collaborative effort of many fields and specializations and hence the commercialization model should be planned to avoid any confusion and disputes at any stage of progress [69].

8.9 Research on Investment Challenges & Economic Analysis :

Research is still open for various issues related to investment challenges, and cold chain economic analysis including following topics in different countries and different industry sectors, and for different commodities [70-73] :

(i) Investment opportunity analysis,
(ii) Operative effectiveness analysis also called performance analysis,
(iii) Techno-economical analysis,
(iv) Socio-economic analysis,
(v) Sustainability or green analysis, etc.

8.10 Research on Social Impact & Empowerment in Developing Countries :

Study on socio-economic analysis on solar cold chain leads to many developmental decisions of country government including further investment to cold chain cycle through annual budgetary investment or Foreign direct investment through business agencies as well as through NGOs to develop the sector systematically. Such investment decisions lead to the empowerment of communities working in the field [74-76].

9. ABCD ANALYSIS OF COLD CHAIN STORAGE SOLUTIONS :

Conceptual Studies & Analysis are also possible in solar cold supply chain systems. This include technology analysis [77], SWOC based opportunity analysis [78-79], ABCD analysis [80-81], predictive analysis [82-83], etc. The research can highlight the opportunities associated with Solar Powered Cold Chain, particularly the positive economic impact that can deliver to the actual farmers and fishermen that grow and catch foodstuffs – enabling larger amounts of income to be earned and retained in the rural economies. The research provides the idea of adopting and managing Solar Cold Chain facilities for farming and fisheries in developing countries through its systematic analysis using the ABCD framework. In ABCD analysis, various determinant issues like producers' point of view, mediators' point of view, consumers' point of view, governments' point of view, and societal point of view are analysed by identifying affecting factors under four constructs - advantages, benefits, constraints, and

disadvantages [84-87].

10. IMPLEMENTATION MODEL :

To implement a megaproject like solar cold supply chain systems as an acceptable model in developed and developing countries as a result of intensive research by many groups through effective monitoring, various resources should be accumulated. The mission of such collaborative teams should be supported through a role model leader with the focussed objectives of serving deprived people in society. The objectives of each group should be identified by visualizing the ideal system in mind. The strategic implementation model should contain a research plan on areas of focus, working groups, accumulation of resources, time frame for research work, Continuous follow up to monitor progress and finally accountability.

(A) Area of Focus :

(1) Material Science Research Group – Solar Panels, Battery Materials& Technology
(2) Mechanical Engineering Group - Refrigeration Systems Research
(3) Food Management & Processing Group – Food quality maintenance & Packaging
(4) Electrical & Electronics Research Group - Effective usage and maintenance of renewable energy
(5) Logistics & Supply Chain Research - an integrated and efficient logistics for transportation of food commodities in Association with ICCT Group.
(6) ICCT Group - to use ICCT underlying technologies like IoT and Blockchain technologies to effective supply chain sensing and detective systems.
(7) Management of Technology Group - Commercialization plan & Models.
(8) Economics Research Group - Investment patterns & economic impact.
(9) Social Science Research Group – Social impact & Empowerment.

(B) Working Groups – Nine Groups :

- (1) Material Science Research Group – Team 1
- (2) Mechanical Engineering Group – Team 2
- (3) Food Management Group – Team 3
- (4) Logistics & Supply Chain Research –Team 4
- (5) ICCT Group – Team 5
- (6) Management of Technology Group –Team 6
- (7) Economics Research Group – Team 7
- (8) Social Science Research Group – Team 8
- (9) Overall Monitoring – Team 9

(C) Time- Frame of development of working proposal :

- (1) Review Paper along with Gap & Research Agenda = 6 Months
- (2) Exact Objective & Research method = 3 Months
- (3) Sub Project Proposals with Requirements for Funding = 3 Months
- (4) Integrated Project Proposal = 4-6 Months
- **Total Period for systematic proposal development = 18 Months**

11. EXPECTED OUTCOME OF PROPOSED RESEARCH :

The proposed research project is on improving the solar cold supply chain system as a sustainable low-cost innovative system to help all its stakeholders to minimize the loss during harvesting/packaging and transportation to identified destinations throughout the world by adopting renewable energy using efficient and mobile energy conversion systems and also adopting smart communicating systems using new generation Information Communication and Computation Technology (ICCT) underlying technologies. Such a developed system not only helps the producers in terms of protecting the quality and freshness of perishable products and the cost of transportation but also automatically identifies destinations which have demand for such products, suggest and guides the logistic system until the rooted products reach their destination. This mega research project even though looks simple andeasy, consists of challenges in many processes from origin to destination and hence needs integrated multi-disciplinary research efforts from experts in many areas and fields.

12. CONCLUSION ;

Systematically planned research on solar powered cold supply chain systems by integrating multidisciplinary concepts and different technologies has the potential opportunity to help many people in perishable commodity production, packaging, transportation to optimum location, effective delivery to destination without suffering quality. This is combined with improving the efficiency of solar panel performance, developments in battery technology, developing uninterrupted Cold Storage and Cold Chain solutions that can be economic to operate, environmentally friendly, and able to be located in rural places where electricity supplies cannot be relied on. The research gap between practical cold supply chain systems and the ideal supply chain system can be minimized by means of practical and applied research in the area of fully integrated Solar Cold Chains. The research highlights the opportunities associated with Solar Powered Cold Chain, particularly the positive economic impact that can be delivered to the actual users in the rural economies. The research provides the idea of adopting and managing Solar Cold Chain facilities for perishable commodities like farming and fisheries in developing countries through its systematic analysis using ABCD framework. This research proposal analyses the opportunities in different subareas of the solar cold supply chain. This strategic implementation model contains a research plan on areas of focus, working groups, accumulation of resources, time frame for research work, Continuous follow up to monitor progress and finally accountability to realize the goal.

REFERENCES :

[1] Aithal, P. S. (2016). Review on Various Ideal System Models Used to Improve the Characteristics of Practical Systems. *International Journal of Applied and Advanced Scientific Research, 1*(1), 47-56. DOI :http://doi.org/10.5281/zenodo.159749.

[2] Aithal, P. S.,&Shubhrajyotsna Aithal, (2015). Ideal Technology Concept & its Realization Opportunity using Nanotechnology, *International Journal of Application or Innovation in Engineering & Management (IJAIEM), 4*(2), 153 – 164. DOI: http://doi.org/10.5281/zenodo.61591.

[3] Aithal, P. S. (2015). Concept of Ideal Business & Its Realization Using E-Business Model. *International Journal of Science and Research (IJSR), 4*(3), 1267 – 1274. DOI :http://doi.org/10.5281/zenodo.61648.

[4] Shubhrajyotsna Aithal &Aithal, P. S. (2018). The Realization Opportunity of Ideal Energy System using Nanotechnology Based Research and Innovations. *International Journal of Advanced Trends in Engineering and Technology*, *3*(2), 1-15, DOI:http://doi.org/10.5281/zenodo.2531876.

[5] Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., &Searchinger, T. (2013). Reducing food loss and waste. *World Resources Institute Working Paper*, 1-40.

[6] Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., &Meybeck, A. (2011). Global food losses and food waste. https://www.madr.ro/docs/ind-alimentara/risipa alimentara/presentation_food_waste.pdf. Retrieved on 01/05/2020.

[7] Islam, S. B., & Habib, M. M. (2013). Supply chain management in fishing industry: A case study. *International Journal of Supply Chain Management*, *2*(2), 40-50.

[8] Viswanadham, N. (2006). Can India be the food basket for the world. *Achieving rural and global supply chain excellence: the Indian way. Hyderabad: GLAMS*, *1*, 1-16.

[9] Hsu, Y. C., Chen, A. P., & Wang, C. H. (2008). A RFID-enabled traceability system for the supply chain of live fish. In *2008 IEEE International Conference on Automation and Logistics* (pp. 81-86). IEEE.

[10] Besik, D., &Nagurney, A. (2017). Quality in competitive fresh produce supply chains with application to farmers' markets. *Socio-Economic Planning Sciences*, *60*, 62-76.

[11] Halder, P., &Pati, S. (2011). A need for paradigm shifts to improve supply chain management of fruits & vegetables in India. *Asian Journal of Agriculture and Rural Development, 1*(393-2016-23908), 1-20.

[12] Negi, S., & Anand, N. (2015). Cold chain: a weak link in the fruits and vegetables supply chain in India. *IUP Journal of Supply Chain Management*, *12*(1), 48.

[13] Zhao, H., Liu, S., Tian, C., Yan, G., & Wang, D. (2018). An overview of current status of cold chain in China. *International Journal of Refrigeration*, *88*, 483-495.

[14] Son, C. H. (2012). A study on the prediction of the future demand for cold-storage facilities in South Korea. *International Journal of Refrigeration*, *35*(8), 2078-2084.

[15] Al-Busaidi, M. A., Jukes, D. J., & Bose, S. (2016). Seafood safety and quality: An analysis of the supply chain in the Sultanate of Oman. *Food Control*, *59*, 651-662.

[16] Rathore, J. (2013). Cold Chain Management for Perishable Food: Issues and Scope for India. *IUP Journal of Supply Chain Management*, *10*(1), 7-14.

[17] Kitinoja, L. (2013). Use of cold chains for reducing food losses in developing countries. *Population*, *6*(1.23), 5-60.

[18] James, S. J., & James, C. (2010). The food cold-chain and climate change. *Food Research International*, *43*(7), 1944-1956.

[19] Hoang, H. M., Brown, T., Indergard, E., Leducq, D., & Alvarez, G. (2016). Life cycle assessment of salmon cold chains: comparison between chilling and superchilling technologies. *Journal of cleaner production*, *126*, 363-372.

[20] Chaudhuri, A., Dukovska-Popovska, I., Subramanian, N., Chan, H. K., & Bai, R. (2018). Decision-making in cold chain logistics using data analytics: A literature review. *The International Journal of Logistics Management*, *29*(3), 839-861.

[21] Sims, R., Flammini, A., Puri, M., & Bracco, S. (2015). Opportunities for agri-food chains to become energy-smart. *UN Food and Agricultural Organisation, Rome and GIZ.*

[22] Wang, X., He, Q., Matetic, M., Jemric, T., & Zhang, X. (2017). Development and evaluation on a wireless multi-gas-sensors system for improving traceability and transparency of table grape cold chain. *Computers and electronics in agriculture*, *135*, 195-207.

[23] Tsang, Y. P., Choy, K. L., Wu, C. H., Ho, G. T., Lam, C. H., & Koo, P. S. (2018). An Internet of Things (IoT)-based risk monitoring system for managing cold supply chain risks. *Industrial Management & Data Systems*, *118*(7), 1432-1462.

[24] Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In *2017 International Conference on Service Systems and Service Management* (pp. 1-6). IEEE.

[25] Rodrigue, J. P., &Notteboom, T. (2015). Looking inside the box: evidence from the containerization of commodities and the cold chain. *Maritime Policy & Management*, *42*(3), 207-227.

[26] Mercier, S., Villeneuve, S., Mondor, M., &Uysal, I. (2017). Time–temperature management along the food cold chain: A review of recent developments. *Comprehensive reviews in food science and food safety*, *16*(4), 647-667.

[27] Verma, H. O., Pal, J., Kumar, J., & Verma, N. (2015). Preliminary study on socio-economic status of fish vendors and market performance of whole sell fish market of district Gorakhpur (Uttar Pradesh). *Int. J. Agricult. Stat. Sci. 11*(1), 2015.

[28] Upadhyay, A. D., & Roy, P. D. (2016). Structural performance of fish market and socio-economic status of market functionaries of Naveen Machhali Mandi Mahanva of Gorakhpur, Uttar Pradesh. *Economic Affairs*, *61*(3), 511.

[29]Madhushree, L. M., Revathi Radhakrishnan & Aithal, P. S. (2019). A Review on Impact of Information Communication & Computation Technology (ICCT) on Selected Primary, Secondary, and Tertiary Industrial Sectors. *Saudi Journal of Business and Management Studies*, 4(1), 106-127.

DOI:http://doi.org/10.21276/sjbms.2019.4.1.14.

[30] Aithal, P. S. &Madhushree, L. M. (2019). Information Communication & Computation Technology (ICCT) as a Strategic Tool for Industry Sectors. *International Journal of Applied Engineering and Management Letters (IJAEML), 3*(2), 65-80. DOI: http://doi.org/10.5281/zenodo.3549423.

[31] Aithal, P. S. &Madhushree L. M. (2019). Emerging Trends in ICCT as Universal Technology for Strategic Development of Industry Sectors. Chapter in a Book - IT and Computing for all the Domains and Professionals: The Emergence of Computer and Information Sciences, Edited by *P.K. Paul, A. Bhuimali, K.S. Tiwary, and P. S. Aithal* published by New Delhi Publishers, New Delhi. pp 1-26, ISBN: 978-93-88879-66-8. DOI :https://doi.org/10.5281/zenodo.3593916.

[32] Aithal, P. S. &Shubhrajyotsna Aithal (2019). Management of ICCT underlying Technologies used for Digital Service Innovation. *International Journal of Management, Technology, and Social Sciences (IJMTS), 4*(2), 110-136. DOI :http://doi.org/10.5281/zenodo.3591139.

[33] Bhuvana R., Madhushree L. M.& P. S. Aithal (2020). Blockchain as a Disruptive Technology in Healthcare and Financial Services - A Review based Analysis on Current Implementations. *International Journal of Applied Engineering and Management Letters (IJAEML), 4*(1), 41-50.

[34] Khalid Mahmood**,** Saad Sarwar, and Muhammad Taqi Mehran (2017). Current status of electron transport layers in perovskite solar cells: materials and properties. *RSC Adv*., 7, 17044-17062.

[35] Sharma, K., Sharma, V. & Sharma, S.S. (2018). Dye-Sensitized Solar Cells: Fundamentals and Current Status. Nanoscale Res Lett 13, 381. https://doi.org/10.1186/s11671-018-2760-6.

[36] Jabbour, G. E., &Doderer, D. (2010). Quantum dot solar cells: The best of both worlds. *Nature Photonics*, *4*(9), 604.

[37] López-Rojas, O., & Guzmán, J. G. (2019, October). A review on quantum dot solar cells: properties, materials, synthesis and devices. In *2019 IEEE International Conference on Engineering Veracruz (ICEV)* (Vol. 1, pp. 1-5). IEEE.

[38] Lim, D. C., Jeong, J. H., Hong, K., Nho, S., Lee, J. Y., Hoang, Q. V., ... & Cho, S. (2018). Semi-transparent plastic solar cell based on oxide-metal-oxide multilayer electrodes. *Progress in Photovoltaics: Research and Applications*, *26*(3), 188-195.

[39] Shaheen, S. E., Radspinner, R., Peyghambarian, N., &Jabbour, G. E. (2001). Fabrication of bulk heterojunction plastic solar cells by screen printing. *Applied Physics Letters*, *79*(18), 2996-2998.

[40] Lin, Q., Lu, L., Tavakoli, M. M., Zhang, C., Lui, G. C., Chen, Z., ... & Chang, P. (2016). High performance thin film solar cells on plastic substrates with nanostructure-enhanced flexibility. *Nano Energy*, *22*, 539-547.

[41] Gasparini, N., Kahmann, S., Salvador, M., Perea, J. D., Sperlich, A., Baumann, A., ... &Portale, G. (2019). Favorable Mixing Thermodynamics in Ternary Polymer Blends for Realizing High Efficiency Plastic Solar Cells. *Advanced Energy Materials*, *9*(19), 1803394.

[42] Kaelin, M., Rudmann, D., & Tiwari, A. N. (2004). Low cost processing of CIGS thin film solar cells. *Solar Energy*, *77*(6), 749-756.

[43] Lee, T. D., &Ebong, A. U. (2017). A review of thin film solar cell technologies and challenges. *Renewable and Sustainable Energy Reviews*, *70*, 1286-1297.

[44] Fraga, D., Barrachina, E., Calvet, I., Stoyanova, T., &Carda, J. B. (2018). Developing CIGS solar cells on glass-ceramic substrates. *Materials Letters*, 221, 104-106.

[45] Xing Luo, Jihong Wang, Mark Dooner, Jonathan Clarke(2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. Applied Energy, 137(1), 2015, 511-536.

[46] Panero, S., Scrosati, B., Wachtler, M., & Croce, F. (2004). Nanotechnology for the progress of lithium batteries R&D. *Journal of power sources*, *129*(1), 90-95.

[47] Xin, S., Yin, Y. X., Guo, Y. G., & Wan, L. J. (2014). A high-energy room-temperature sodium-sulfur battery. *Advanced Materials*, *26*(8), 1261-1265.

[48] Pal, A. K., & Potter, H. C. (2019). Advances in Solar Energy: Solar Cells and Their Applications. In *Advances in Solar Energy Research* (pp. 75-127). Springer, Singapore.

[49] Gong, J., Li, C., &Wasielewski, M. R. (2019). Advances in solar energy conversion. *Chemical Society Reviews*, *48*(7), 1862-1864.

[50] Shubbak, M. H. (2019). Advances in solar photovoltaics: Technology review and patent trends. *Renewable and Sustainable Energy Reviews*, *115*, 109383.

[51] Jamesh, M. I. (2019). Recent advances on flexible electrodes for Na-ion batteries and Li–S batteries. *Journal of Energy Chemistry*, *32*, 15-44.

[52] Simon, P., Gogotsi, Y., & Dunn, B. (2014). Where do batteries end and supercapacitors begin?. *Science*, *343*(6176), 1210-1211.

[53] Hossain, A., Saha, S., Rahman, M. A., &Himel, M. A. (2019, May). Low Power Consuming Solar Assisted Vapor Compression Refrigerator to Preserve Emergency Medicines and Vaccines in Rural Areas. In *2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT)* (pp. 1-6). IEEE.

[54] George, R. M. (1993). Freezing processes used in the food industry. *Trends in Food Science & Technology*, *4*(5), 134-138.

[55]Bhuvana, R. & Aithal, P. S. (2020). RBI Distributed Ledger Technology and Blockchain - A Future of Decentralized India. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *5*(1), 227-237. DOI: http://doi.org/10.5281/zenodo.3839780.

[56] Abdel-Basset, M., Manogaran, G., & Mohamed, M. (2018). Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems. *Future Generation Computer Systems*, *86*, 614-628.

[57] Krishna Prasad, K., Vinayachandra, K., Geetha Poornima, & Rajeshwari, M. (2020). Literature Review of Applications of ICT on Solar Cold Chain. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *4*(1), 93-111. DOI: http://doi.org/10.5281/zenodo. 3779806.

[58] Krishna Prasad, K., Vinayachandra, K., Geetha Poornima, & Rajeshwari, M. (2020). An Integrated Solution for Solar Cold Chain Portfolio Management using Internet of Things. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *4*(1), 112-130. DOI: http://doi.org/10.5281/zenodo.3780575.

[59] Galvez, J. F., Mejuto, J. C., &Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *TrAC Trends in Analytical Chemistry*, *107*, 222-232.

[60] Wang, Y., Han, J. H., & Beynon-Davies, P. (2019). Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management: An International Journal*. 24(1), 62-84.

[61] Bocek, T., Rodrigues, B. B., Strasser, T., & Stiller, B. (2017, May). Blockchains everywhere-a use-case of blockchains in the pharma supply-chain. In *2017 IFIP/IEEE symposium on integrated network and service management (IM)* (pp. 772-777). IEEE.

[62] Malhotra, B., Keshwani, A., &Kharkwal, H. (2015). Antimicrobial food packaging: potential and pitfalls. *Frontiers in microbiology*, *6*, 611.

[63] Cao, S., Hu, Z., Pang, B., Wang, H., Xie, H., & Wu, F. (2010). Effect of ultrasound treatment on fruit decay and quality maintenance in strawberry after harvest. *Food Control*, *21*(4), 529-532.

[64] Leistner, L. (2000). Basic aspects of food preservation by hurdle technology. *International journal of food microbiology*, *55*(1-3), 181-186.

[65] Vega-Mercado, H., Martin-Belloso, O., Qin, B. L., Chang, F. J., Góngora-Nieto, M. M., Barbosa-Cánovas, G. V., & Swanson, B. G. (1997). Non-thermal food preservation: pulsed electric fields. *Trends in Food Science & Technology*, *8*(5), 151-157.

[66] Zambrano-Zaragoza, M. L., González-Reza, R., Mendoza-Muñoz, N., Miranda-Linares, V., Bernal-Couoh, T. F., Mendoza-Elvira, S., &Quintanar-Guerrero, D. (2018). Nanosystems in edible coatings: A novel strategy for food preservation. *International Journal of Molecular Sciences*, *19*(3), 705.

[67] Dmitriev, V., Simmons, G., Truong, Y., Palmer, M., &Schneckenberg, D. (2014). An exploration of business model development in the commercialization of technology innovations. *R&D Management*, *44*(3), 306-321.

[68] Aithal, P. S., & Aithal, S. (2016). Nanotechnology Innovations and Commercialization–Opportunities, Challenges & Reasons for Delay. *International Journal of Engineering and Manufacturing (IJEM)*, *6*(6), 15-25.

[69] Aithal, P. S., & Aithal, S. (2016). A New Model for Commercialization of Nanotechnology Products and Services. *International Journal of Computational Research and Development*, *1*(1), 84-93.

[70] Wang, M., & Zhao, L. (2018). Cold chain investment and pricing decisions in a fresh food supply chain. *International Transactions in Operational Research*.

[71] Sharma, S., & Pai, S. S. (2015). Analysis of operating effectiveness of a cold chain model using Bayesian networks. *Business Process Management Journal*.

[72] Joshi, R., Banwet, D. K., Shankar, R., & Gandhi, J. (2012). Performance improvement of cold chain in an emerging economy. *Production Planning & Control*, *23*(10-11), 817-836.

[73] Huo, B. (2019). Research on Green Food Cold Chain Planning and Urbanization Economic Development Path Analysis. *ArchivosLatinoamericanos de Nutrición*, *69*(1), 1-12.

[74] Negi, S., & Anand, N. (2015). Cold chain: a weak link in the fruits and vegetables supply chain in India. *IUP Journal of Supply Chain Management*, *12*(1), 48.

[75] Singh, B. K., & Negi, S. (2018). Cold chain logistics: an impediment in the perishable food industry of India. *International Journal of Logistics Economics and Globalisation*, *7*(4), 332-352.

[76] Bharti, A., & Mittal, A. (2018). Perishable goods supply cold chain management in India. In *Supply Chain Management Strategies and Risk Assessment in Retail Environments* (pp. 232-246). IGI Global.

[77] Aithal, P. S. and Shubhrajyotsna Aithal (2018). Study of various General-Purpose Technologies and their contribution towards developing Sustainable Society. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *3*(2), 16-33, DOI :http://doi.org/10.5281/Zenodo.1409476.

[78] Padma, S. R., &Rathakrishnan, T. (2013). SWOC Analysis on Precision Farming System. *Journal of Global Communication*, *6*(2), 96-102.

[79] Aithal, P. S., & Kumar, P. M. (2015). Applying SWOC Analysis to an Institution of Higher Education. *International Journal of Management, IT and Engineering*, *5*(7), 231-247.

[80] Aithal, P. S. (2016). Study on ABCD analysis technique for business models, business strategies, operating concepts & business systems. *International Journal in Management and Social Science*, *4*(1), 98-115. DOI :http://doi.org/10.5281/zenodo.161137.

[81] Aithal, P. S., Shailashree, V., & Kumar, P. M. (2015). A new ABCD technique to analyze business models & concepts. *International Journal of Management, IT and Engineering*, *5*(4), 409-423.

[82] Shubhrajyotsna Aithal & Aithal, P. S. (2018). The Realization Opportunity of Ideal Energy System using Nanotechnology Based Research and Innovations. *International Journal of Advanced Trends in Engineering and Technology*, *3*(2), 1-15. DOI :http://doi.org/10.5281/zenodo.2531876.

[83] Aithal, P. S. &Shubhrajyotsna Aithal (2019). Building World-Class Universities : Some Insights & Predictions. *International Journal of Management, Technology, and Social Sciences (IJMTS), 4*(2), 13-35. DOI:http://doi.org/10.5281/zenodo.3377097.

[84] Aithal, P. S., & Aithal, S. (2018). Factor & Elemental Analysis of Nanotechnology as GreenTechnology using ABCD Framework. *International Journal of Management, Technology, and Social Sciences (IJMTS), 3*(2), 57-72.

[85] Aithal, P. S. (2017). ABCD Analysis as Research Methodology in Company Case Studies. *International Journal of Management, Technology, and Social Sciences (IJMTS), 2*(2), 40-54.

[86] Aithal, P. S. & Suresh Kumar, P. M. (2016). CCE Approach through ABCD Analysis of 'Theory A' on Organizational Performance. *International Journal of Current Research and Modern Education (IJCRME), 1*(2), 169-185. DOI: http://dx.doi.org/10.5281/zenodo.164704**.**

[87] Raj, K., & Aithal, P. S. (2018). Generating Wealth at the Base of the Pyramid–A Study using ABCD Analysis Technique. *International Journal of Computational Research and Development (IJCRD), 3*(1), 68-76.

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