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EDITORIAL

UNCERTAINTY IS THE ONLY CERTAINITY UNDER CORONA CATASTROPHICAL CALAMITIES

We are extremely happy to present this issue (NSV 16, June 2020, No.1) to our readers even under abnormal circumstances worldwide. We express our sincere thanks to all our contributors, evaluaters, readers and well wishers for their continuous and consistent support which has always helped us to achieve our goal.

This issue contains in all **two articles, six research articles, two review articles** and **one biography** alongwith other items as usual. On the occassion of Statistics Day Celebration on 29th June, 2020, **one special article** is presented by **Jayesh R. Purohit** highlighting **Prof. P. C. Mahalanobis** and his work.

Under the caption of **Management and statistics**, there are **three research articles**. **First research article** describes supply chain management issues, It has been furnished by **Ajay K. Aggarwal, Dinesh S. Dave and Varinder Sharma.**

Second research article discusses important issues connected with Ph.D. programme with emphasis for India. It is given by **A. C. Brahmbhatt**.

Third Article by **Jayesh R. Purohi**t explains briefly about recent developments in Inventory Management. There are other **four research articles and two review articles.**

Among them **first research article** discusses COVID-19 issues with its implications for Indian economic scenario. It has been presented by **Ranjan Gohil** and **Pradeep P. Prajapati**.

Second research article discusses adaptive design clinical trials and related issues. It is presented by **Pinakin R. Jani**.

Third research article describes interesting work connected with mutually orthogonal latin square design with application to magic square. It is discussed by **D. K. Ghosh.**

Fourth research article discusses an application related with Microsoft company. It is presented by **Sanjay G. Raval** and **Vernal R. Danior**.

Among **two review articles, first review article** introduces second part for

clinical trials and statistical analysis. It is furnished by **Pinakin R. Jani.**

Second review article is the work discussed by **Pinakin R. Jani** and **Manish B. Thaker** explaining present Covid-19 issues.

Biographical Sketch for **Debbrata Basu** is presented by **H. D. Budhbhatti.**

Readers forum provides readers views and suggestions. It is given by **A. M. Patel.**

We are highly indebted to our following referees who have done excellent job of evaluations of articles / papers etc, which are submitted in this issue.

(Their names are given one by one inorder of their appearanc ein the journal)

(1) H. S. Mediwala	**(2) P. Mariappan**
(3) R. G. Bhatt	**(4) D. S. Dave**
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(11) Shailesh Teredesai	

We have started our website since last one year. You can also meet us on **www.sankhyavignan.org** and give your feedback and suggestions.

We express our sincere thanks to **Shri Ashish Bhatt for webstie, Shree Dinesh Darji for DTP work and Shree Mehul Shah for printing work**.

Digital copy of this issue will be sent to all our readers whose emial ID/ What'sapp No. are registered with us. Printed copy may follow soon. Our contributors will get offprints of their published articles along with the printed copy and certificate.

WISH YOU GOOD HEALTH, FURTHER PROGRESS AND PROSPERITY.

AHMEDABAD **EDITORIAL BOARD**

Date : 29/06/2020

NOTE : Members of editorial board are in no way concerened with the views, opinions or ideas expressed in this issue. Authenticity responsibility lies solely with the persons presenting them.

ARTICLE

FOOTPRINTS ON THE SANDS OF TIME : PROF P C MAHALANOBIS

Jayesh R. Purohit*

Prof. Prasanta Chandra Mahalanobis is also known as the father of Indian Statistics. He was a physicist by training, a statistician by instinct and a planner by conviction. His contributions were massive on the academic side as the builder of the Indian Statistical Institute, organizer of the Indian statistical systems, pioneer in the applications of statistical techniques to practical problems, architect of the Indian Second Five Year Plan, and much more. Statistical science was a virgin field and practically unknown in India before the twenties. Developing statistics was like exploring a new territory. It needed a pioneer and an adventurer like him, with his indomitable courage and tenacity to fight all opposition, clear all obstacles, and throw open wide pastures of new knowledge for the advancement of science

Prof. Prasanta Chandra Mahalanobis perceived statistics 'as a universal tool of inductive inference, research in natural and social sciences, and technological applications' and 'as a key technology for increasing the efficiency of human efforts in the widest sense' and society.

Early life

Prof. Prasanta Chandra Mahalanobis was born into a family well established in Calcutta (Kolkata), who were relatively wealthy and whose members were enterprising, adventurous, imbued with liberal Brahmo Samaj traditions and active in all Bengali life. He was born on 29th June 1893 at 210 Cornwallis Street (his grandfather's house) as the elder son among two sons and four daughters of Probodh Chandra Mahalanobis and Nirodbasini Devi. The family background and the contacts he had with the great intellectuals and social reformers of Bengal cut him out for

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the active life he had to lead over the next seventy years.

Family

Prof. Prasanta Chandra Mahalanobis' actual surname was "Bandyopadhaya". Possibly six generations before, Guru Charan Mahalanobis started using the surname Mahalanobis as he was appointed to keep the accounts of land and land revenue of Mahal of ancient Bengal. They knew him as "Nauvice". In Persian "nauvice" means scribe of Mahal (A Mughual administrative unit), so his surname "Mahalanobis" came from the concept of "Mahal" and "Nauvice". Prasanta Chandra Mahalanobis's roots were in Panchasar village, now in Vikrampur, Bangladesh. Prasanta Chandra Mahalanobis's grandfather was Guru Charan Mahalanobis who was follower of Sadharan Brahmo Samaj.

His father was Probodh Chandra Mahalanobis, a pioneering entrepreneur, who successfully ran a dealership in sports goods, gramophones and records. Through this efforts, the first successful recording of Rabindranath Tagore's voice was made in 1924. Prof. Prasanta Chandra Mahalanobis's mother was Nirodbasini Devi, who was the sister of Dr. Nilratan Sircar, the eminent physician, educationist, and industrialist of that time.

Education

He started his education at Brahmo Boys' School, which was founded by his grandfather Guru Charan Mahalanobis in 1904. Prof. Prasanta Chandra Mahalanobis earned a Bachelor degree in Science with Honours in Physics from the Calcutta University under Presidency College in 1912, before he sailed to England and joined Cambridge University He obtained Mathematics Tripos part I in 1914, and Physics Tripos part II in 1915 from Cambridge University.

As a student, Prof. Prasanta Chandra Mahalanobis never confined himself in his subject books. He was very interested in various subjects like amateur astronomy, philosophy, architecture and psychology. Around this time, Prasanta Chandra Mahalanobis met with pioneer of Mathematics Srinivasa Ramanujan in Cambridge. He had his initiation in Statistics in 1915 through Biometrika, the journal founded by Karl Pearson.

Early career

He first joined Presidency College in 1915 as a temporary Professor. In 1922

he became Asst. Professor of Physics and taught Physics for 33 years (1915-1948). He was also the Principal of Presidency College for a few years and held the post of Meteorologist in the Alipore Observatory in Calcutta from 1922 to 1926.

Life companion

Prof. Prasanta Chandra Mahalanobis married Nirmal Kumari (nicknamed Rani), who was the daughter of Puritan Brahmo leader and educationist of Bengal Heramba Chandra Moitra. Nirmal Kumari was the person who stood by the Prof. Prasanta Chandra Mahalanobis in all his struggles, helped him in all his endeavours and exercised a great influence on his life. She often accompanied Prof. Prasanta Chandra Mahalanobis on his frequent tours abroad. Their companionship lasted for 49 years until the death of Mahalanobis.

Influence of great minds

Rabindranath Tagore, Prof. Prasanta Chandra Mahalanobis, and Nirmal Kumari Mahalanobis shared a unique relationship. Rabindranath Tagore used to take a keen interest in Prof. Prasanta Chandra Mahalanobis's statistical work from the very beginning. Even his career in statistics was very largely influenced by the poet. When Prof. Prasanta Chandra Mahalanobis expressed his interest to work on Statistics, he approached Rabindranath Tagore for his kind opinion. Tagore sent him to meet with Dr. Brajendranath Seal (B.N.Seal). He was further encouraged to engage in statistical research by B. N. Seal who asked him to take up a certain statistical exercise with respect to the examination result of Calcutta University.

Establishment of Indian Statistical Institute

At the time Prof. Prasanta Chandra Mahalanobis was a Professor of Physics at Presidency College, he was highly involved in the work of statistics. He set up the Statistical laboratory in the baker laboratory of Presidency College, Calcutta, in the early 1920s. In the initial phase, his statistical research was in anthropometry, in meteorology and in problems of flood control in North Bengal and Orissa.

On 17th December, 1931, Prof. Prasanta Chandra Mahalanobis set up the Indian Statistical Institute for advanced research and training in statistics. Later during the 1950s, ISI shifted to the present premises at Baranagar, a suburb of Kolkata, West

Bengal. In 1932, the Institute was located in a small portion of the Physics Department of the Presidency College but by 1972 the Institute had several large building of its own to provide working space for research and training in diverse subjects such as: anthropometry, biochemistry, botany, computer science, crop science, economics, human genetics, pre census, psychometry, sociology, and statistics. The Institute's activities were not confined within Calcutta but spread all over the India.

While Prof. Prasanta Chandra Mahalanobis struggled against many odds in his bid to develop statistics as a science in India, he was lucky to receive whole hearted cooperation and help from a number of people. He had a special ability for locating talents. From the very beginning of the Institute he was assisted by a number of young and talented researchers, namely Harish Chandra Sinha, Raj Chandra Bose, Samarendra Nath Roy, and Keshvan Raghavan Nair. In 1941 came Calyampudi Radhakrishna Rao. That Mahalanobis was not wrong in his selection of comrades-in-arms was evident from the fact that many of his early associates earned international fame for themselves and the Institute for their outstanding contributions to statistics.

Indian Statistical Institution started courses of study leading to the degrees of Bachelor of Statistics and Master of Statistics from July, 1960 and also made arrangement for the award of Degrees Ph.D. and D.Sc. in Statistics.

The First Convocation of the Indian Statistical Institute was held in the mango-grove of the Institute on 12 February 1962. The event of first convocation was marked with the conferment of Honorary Doctor of Science to five eminent people: **Professor Satyendra Nath Bose, Sir Ronald Aylmer Fisher, Sri Jawaharlal Nehru, Academician Andrey Nikolaevich Kolmogorov and Dr. Walter Andrew Shewhart**. During the first convocation, the Degree of Doctor of Philosophy was conferred to two students, Kalyanapuram Ranga Parthasarathy and Jayaram Sethuraman, and Master of Statistics Degree to Narasimha Sreenivasa Iyengar, Vasant Tukaram Korde, Tares Maitra, Manjula Mukhopadhyay, Ganesan Parthasarathy, Kadiyala Koteswara Rao, and Paras Nath Singh.

Contribution to the field of Statistics

The anthropometric studies led to the formulation of D2- Statistic, known in statistical literature as Mahalanobis Distance, which has proved to be a valuable tool not only in taxonomy but in many other fields including economics and geology.

A rich field of research in multivariate analysis opened up; Sir Ronald Aylmer Fisher (R. A. Fisher) accepted this concept by giving it the name 'Mahalanobis D-square' or 'Mahalanobis distance',

Prof. Prasanta Chandra Mahalanobis was again called upon to tackle the problem of flooding after two devastating floods, one in North Bengal in 1922 and the other in Orissa in 1926. This led him to undertake extensive statistical studies of rainfall and floods in Bengal and Orissa covering a span of about sixty years. The studies yielded some of the basic calculations that were later used for the two hydro-electric and irrigation projects in Hirakud and Damodar Valley.

Prof. Prasanta Chandra Mahalanobis' first systematic work was on a statistical study of the anthropometric measurements of Anglo-Indians in Calcutta and his first paper was on "Anthropological Observations on the Anglo-Indian of Calcutta Part-I Analysis of Male Stature' urt", which was published in the records of the Indian Museum in 1922.

Sankhya, The Indian Journal of Statistics**,** founded by Prof. Prasanta Chandra Mahalanobis in 1933 is the official publication of Indian Statistical Institute. Prof. Prasanta Chandra Mahalanobis explained his reasons for choosing the name *Sankhya*. In his words: "We believe that the idea underlying this integral concept of statistics finds adequate expression in the ancient Indian word Sankhya. In Sanskrit the usual meaning is 'number', but the original root meaning was 'determinate knowledge" He was the editor of *Sankhya* from 1933 to 1972.

Then came the epoch-making investigation on the technique of large scale sample surveys, with which Prof. Prasanta Chandra Mahalanobis' name will always be associated. Systematic work on the surveying of agriculture crops began in 1937, which culminated in a large scale sample survey of the acreage and yield of jute crop in 1941. It covered the whole province of Bengal and was extended to all important crops in both Bengal and Bihar in 1943.

This was followed by sample surveys for collecting socio-economic data, such as public preference. A large number of surveys were conducted from 1937-1950 in Bengal for collecting information on crops and socio-economic data, which gave opportunities for improving the design of sample surveys and for gaining experience in the collection of data from the field. During the sample census on jute crop in Bengal, Prof. Prasanta Chandra Mahalanobis insisted on the use of sampling

methodology. But the Government officials had no idea about sampling and the survey was on the verge of being abandoned altogether.

At this juncture, R. A. Fisher came to India in 1938 and in a memorandum submitted to the Viceroy, he strongly recommended the use of sampling methodology in India. At last a large scale sample survey of the area under jute for the whole province of Bengal was undertaken in 1940. Several hurdles had to be crossed in convincing the administrators that gaps in national income statistics could be filled through data obtained by sampling, and that there would be a need for continuous collection of information to assess the progress of economic development and to make policy decisions.

Prof. Prasanta Chandra Mahalanobis won the battle and the **National Sample Survey** was established in **1950**. It is a continuing survey in which information is collected year by year with the help of a whole time field organization, spread all over India, and which provides periodic estimates on social and economic factors affecting the nation economy. A Central Statistical Unit was established by the Government of India in 1949 to work under the technical guidance of Prof. Prasanta Chandra Mahalanobis as Honorary Statistical Adviser to the cabinet. For more than two years this unit was entirely staffed from and run by ISI. After two years the Central Statistical Organizations was formed for coordinating all statistical activities of the Government.

After meeting with Dr. Walter Shewart, who was known as the 'Father of Statistical Quality Control', Prof. Prasanta Chandra Mahalanobis wrote to the Government of India in 1942 pointing out the advantages of using statistical quality control methods, particularly in the industries. As a consequence, the Indian Statistical Institute took initiative in spreading the use of quality control methods in industry by establishing **Statistical Quality Control** units in different parts of India since 1953. Even when Prof. Prasanta Chandra Mahalanobis was working on his planning models, he had not stopped giving new ideas in statistical methodology. In 1958 he found a simple but very effective technique known as Fractile Graphical Analysis.

Start of a new era: introduction of computers

Prof. Prasanta Chandra Mahalanobis was one of the first people in the country to recognize the importance of machines – mechanical, electrical as well as electronic

– to make fast, accurate and complicated calculations with masses of figures. In the 1950s, Prof. Prasanta Chandra Mahalanobis arranged to have a large number of electromechanical data processing machines from IBM; the Hollerith and the Power Samas varieties were installed to process NSS data. Through his initiative in 1953, a small analog computer was designed and built in the Institute.

In 1956, Prof. Prasanta Chandra Mahalanobis arranged for the installation of a British made digital computer, the HEC-2M, Hollerith – Electronic Digital Computer, the first of its kind to be in operation anywhere in India. During 1955, the USSR Government had offered the Institute a big electronic digital computer called URAL through the UNTAA (United Nations Technical Aid Administration). The URAL computer was received in March 1958 and installed on 20 December 1958 in the Institute for the processing of statistical data by the Soviet engineers who handed it over for use in February 1959. By 1959-60, the Indian Statistical Institute became, for all practical purposes, a National Computer Centre for the country. It met the computational requirements for scientific problems in organizations like the Ministry of Defence, The Atomic Energy Commission, the Tata Institute of Fundamental Research and the Meteorology Department. The first solid state digital computer in India, ISIJU-1, was designed, developed and constructed by the engineers of the Institute in collaboration with the Jadavpur University in 1965.

Contribution of ISI: excavation of a dinosaur

In 1957, Prof. Prasanta Chandra Mahalanobis invited Dr. Pamela Robinson of the University College London to the ISI to set up the Geological Studies Unit. The team under the leadership of Dr. Pamela Robinson discovered for the first time in India the fossil bones of the giant prehistoric lizard; the largest animal that lived on the earth. Over ten tons of bone material were collected from the Pranhita–Godavari valley and brought to Calcutta. The bones were assembled and later mounted in 1976, in record time into a full length skeleton of the dinosaur in the Geological Studies Unit. The skeleton was named Barapasaurus tagorie.

Contribution to national development

Prof. Prasanta Chandra Mahalanobis played an important role in Indian National Economic Planning. He took major responsibility in drafting the Second Five Year

Plan for India. He believed in perspective planning and used simple logical ideas in deriving an economic model for planning in an under developed country, like India.

As a member of the Planning Commission, he sold the idea of making large investments in heavy industries, setting aside other sectors of development, a policy which helped the country considerably in rapid industrialization.

Dignitaries at ISI

The growing importance of the Institute was reflected in the continuous inflow of visitors, over a thousand leading scientists of the world visited the Indian Statistical Institute. Many of these scientists spent long periods of time at the institute and often stayed with Mahalanobis at his residence. From 1937 to 1967 about six hundred leading scientists and economists of the world came to the Institute, among them were **J.B.S. Haldane, Abraham Wald, J.K. Galbraith, Frederic Joliot-Curie, Madame Irene Joliot-Curie, Norbert Weiner, Chou-en-Lai, Prime Minister of China, Ho-chi-minh, and President of the People's Republic of Vietnam** to name a few.

International liaisons with ISI

As the Indian Statistical Institute started earning international fame, Prof. Prasanta Chandra Mahalanobis was becoming more and more preoccupied with assignments outside. Prof. Prasanta Chandra Mahalanobis worked for international understanding and collaboration in scientific research with foreign scientists.

Prof. Prasanta Chandra Mahalanobis started going abroad from 1946 in connection with the work at the United Nations Statistical Commission in various capacities: as member; Vice-Chairman and Chairman; as its representative on the Population Commission in 1948; and as a member of drafting committee at the Regional Meeting of Statisticians. Prof. Prasanta Chandra Mahalanobis attended all the sessions of the Statistical Commission from the Nuclear Session in February-June 1946, to the 16th session in October 1970—an unparalleled record. Prof. Prasanta Chandra Mahalanobis chaired the Conference of Statisticians of the United Nations Economic Commission for Asia and the Far East, ECAFE (now Economic and Statistical Commission for Asia and Pacific, ESCAP) in 1952.

Awards and accolades

Prof. Prasanta Chandra Mahalanobis received a number of awards and honours in India and abroad for his outstanding and fundamental contribution to Statistics and Planning.

He was elected as fellow of the:

- Royal Society of London in 1945,
- Chairman of the United Nations Sub- Commission on Statistical Sampling (five sessions- 1947-1951)
- Fellow of International Econometric Society (1951)
- Chairman of United Nations Statistical Commission (1954-1958)
- President of National Institute of Sciences of India (1957 and 1958)
- Fellow of American Statistical Association (1961)
- Fellow of World Academy of Art and Science (1963).

Prof. Prasanta Chandra Mahalanobis was honoured with several awards:

-The Weldon Medal from Oxford University (1944),
- Sir Devaprasad Sarbadhikari Gold Medal from Calcutta University (1957),
- Gold Medal from Czechoslovak Academy of Sciences (1964),
- Durga Prasad Khaitan Memorial Gold Medal from Asiatic Society (1968),
- Srinivasa Ramanujan Gold Medal (1968),
- Honorary Deshikottama from Visva Bharati University (1961).

In 1968, he was awarded the Padma Vibhushan, the second highest civilian award by the Republic of India for his contribution to science and services to the country. He also received honorary doctorates from Calcutta University (1957), Sofi University (1961), Delhi University (1964) and Stockholm University (1966).

Prof. Prasanta Chandra Mahalanobis viewed statistics not as a branch of mathematics but as a technology. Mathematics and probability theory are only the means to promote the use of statistical methods in the world of reality. He shaped Indian Statistical Institute as a beacon of knowledge with commitment for national development and social welfare. He is still being remembered for the Mahalanobis Distance, a statistical measure, and for his great contribution in the large scale sample survey. He continues to inspire statisticians in India and around the world.

MANAGEMENT AND STATISTICS
RESEARCH ARTICLE

A NEW PARADIGM FOR THE MATERIALS FLOW IN SUPPLY CHAINS; AN OVERVIEW

Ajay K. Aggarwal[1], Dinesh S. Dave[2] and Varinder Sharma[3]

ABSTRACT

Supply Chain Management (SCM) is the most critical function in today's competitive environment. SCM coordinates all activities and processes starting from the fundamental raw materials to the manufacturers to the distributors until the final product reaches to the end-consumers. Due to the globalization, companies in the chain of supply are located in different parts of the world which makes the supply chain network more complex. The benefits of global supply chain management include low cost and the possibility of introducing the product to the market of different countries. When the companies become part of the global supply chain network, the management often face with a variety of risks. This study presents the impact of the current pandemic on the materials flow of the chain of supply. Additionally, the study discusses the Just-in-Case approach as compared to Just-in-Time approach to resilient the global supply chain.

KEY WORDS

Covid-19, GSCM, JIT, JIC

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1. INTRODUCTION

Supply chain management is the coordination of all activities - from raw materials to the finished product, including reverse logistics or recycling. As the world has become interconnected, the simple supply chains have transformed into more complex, robust, networked, global supply chains. Due to the globalization in supply chain networks, materials management of supply chains has become very challenging. Coupled with the environmental uncertainty in general, and Covid-19 pandemic in particular, the complexity of the management of materials flow has exacerbated. Far from presenting optimal or plausible solutions, the traditional inventory policies based on the just-in-time approach with safety or buffer stock are not equipped to handle the massive disruptions characterizing the prevailing situation. The current paper suggests a viable alternative based on a just-in-case approach that has the potential to safeguard materials flow during periods of catastrophic demand fluctuations, such as the Covid-19 pandemic phase. Predicated on a comprehensive what-if analysis, the just-in-case method would make a priori contingency plans an essential element of supply chain management.

Supply chain management is the coordination of all activities starting from the receipt of raw materials to delivery of the finished product to the end consumer, including post-use recycling and reverse logistics. A supply chain includes companies supplying the raw material, manufacturing companies, distributors, wholesale organizations, and retail companies. As the world has grown "flat" through interconnectivity, the simple domestic supply chains have transformed into more complex, robust, networked, global supply chains involving organizations around the world. Several factors have served as catalysts in this change, including technological advancement, trade agreements, raw material availability, availability of cheaper labor, environmental, economic and political situations, cultural issues, and purchasing power. In a nutshell, the main objective of the supply chain is to deliver the right material, at the right price, at the right time, at the right place, with the right condition, with the right quality. Wisner (2017) describes supply chain as a network of companies or entities that produce goods and services for the consumers. In the global supply

chain, these organizations are located in different parts of the world which makes the supply chain network more complex.

Many research studies have described materials, financial, and information flows and their roles in the supply chain network (Dave, et al., 2016 and Dave, et al., 2018). According to Stadtler (2005), supply chain management integrates organizational units in the network and coordinates these flows to satisfy customer demands and enhance competitiveness. Lately, due to the pandemic, the materials flow which is the actual movement of product or raw material across the network, has been gaining more attention. The entities in the supply chain network optimize the material flow to deliver products to the customers at the right price at the right time. One of the ways to achieve this goal is to optimize inventory, logistics, and manufacturing costs. Also, entities or the partners in the network work together to streamline the material flow in order to reduce waste. Effective management of the materials requires a systems approach and coordination between supply chain partners (Sahin and Robinson, 2002).

Lately, the supply chain managers have been the recipient of a plethora of comments from around the world. Political leaders, business executives, news reports, medical professionals, and consumer groups have quickly realized the critical role of supply chains in our daily lives. As a result, any disruption in the supply chain network has the potential to impact our lives detrimentally. Recently, Aggarwal and Dave (2019) discussed an approach for managing supply chain risk. Due to the Covid-19 pandemic, consumers around the world have experienced scarcity of essential commodities including food and medical supplies. Additionally, Covid-19 has in addition to disrupting the world economy and everybody's lifestyle, afflicted millions and claimed hundreds of thousands of lives.

The materials flow which mostly deals with the management of inventory has become extremely critical during the Covid-19 crisis. The dynamic nature of today's business environment coupled with the impact of these factors makes managing global supply chains a challenge for business executives. Since 2019, global events such as the coronavirus pandemic, ongoing tariff wars, Middle East volatility, Brexit, and

the world's overdependence on Southeast Asia - particularly China - as a producer of key goods have alarmed countries across the globe. The concerns are exacerbated when confronted with the stark reality that no country currently has the infrastructure, socio-economic conditions, and ability to replace Southeast Asia outright.

Researchers have extensively developed deterministic and stochastic inventory models to address the materials cost. These models incorporated inventory related costs, production cost, safety stock, buffer stock, transportation cost, etc. Additionally, researchers suggested methods and models of lowering inventory and developed the JIT approach. These concepts are useful when the business environment is normal. As supply chains become more complex, management is faced with various uncertainties. These uncertainties arise from the fluctuation in customer demand, variation in lead-time, delivery time variation, variation in suppliers' capacity, etc. In order to address these uncertainties, the management constantly wrestles with the issue of the shortage of both work-in-process and finished goods inventories. On the flip side, misjudging consumer demand has the potential of creating bloated inventories caused by the bullwhip effect (Aggarwal and Dave, 2018). These problems are exacerbated when dealing with catastrophic events like the Covid-19 pandemic. Business executives face a challenge to implement just-in-time to lower the cost or to stockpile items to safeguard the company's operations, just-in-case. While the procedures for implementing the just-in-time paradigm are well established in the literature, discussions of a plausible ***just-in-case*** approach are presented.

2. JUST-IN-CASE APPROACH TO SUPPLY CHAIN MATERIAL MANAGEMENT

Just-in-case is the traditional inventory management used under which, firms used to keep large stockpiles of both the raw material as well as finished goods inventories for immediate meeting unexpected demand surges (e.g., L'abbe Wu, 1989 and Kerr and Houghton, 2010), which might take place due to any of the unexpected hazards such as fire accident at a supply chain site or flooding, or labor strikes. Over time following the unprecedented success of Toyota Motors, most of the global

companies started mimicking the Toyota model of inventory and started replacing the JIC with the JIT system of inventory management. The JIT inventory system has merits such as low inventory cost, thereby enabling firms to keep more cash with them rather than investing in the unused inventory, however, such a system assumes that the raw material will be available on demand. Disruptions such as those created by COVID-19 create abnormal conditions such as stockouts of merchandise in the immediate aftermath of the disrupting event. JIT, in principle, is not designed to handle sudden disruptions, however, JIC with excess inventory can enable a firm to scale up production and meet immediate needs of the market.

Are the pandemics going to be regular in future or COVID-19 is the last one? It is difficult to predict especially when they result from direct or indirect behavior of an entity. Firms can't live in a state of such uncertainty, they need to plan to become resilient to such disruptions whether randomly generated or intentionally created. Therefore, we see the relevance of JIC as an essential part of inventory management. Though, it will require investment in unused inventory but such an investment would be far more profitable for the firm as it will enable the firm to be flexible in dealing with disasters and avoid stockouts, which according to Sheffi and Price (2005) may create a competitive advantage for the firm.

Managers are generally comfortable with decision models employing the what-if approach. It basically suggests an alternative course of action if a particular condition is realized. The authors suggest applying this simple, yet effective model at each stage in the supply chain to the supplier network providing materials input. For every input that is consumed during the supply chain stage, the manager will determine the potential courses of action when the input supply is disrupted. This could include an alternate supplier or suppliers that are kept informed of their potential need, and who would in turn design their own operations in anticipation of being able to fulfill emergent needs. If alternate suppliers could not be found for the stage, other alternatives could be additional inventories to make up for the short supply, or vertical integration to self-source. In addition, suppliers of substitute products that can essentially accomplish the task may be considered to make up for any shortfall. In

order to work effectively at any stage the what-if approach required significant collaboration between all players. There would need to be a win-win agreement between the supply chain stage managers and all potential suppliers. For the vertical integration option to be viable, the facility has to be operational with all the requisite know-how and materials on hand. Managing the cost of employing the what-if approach across all stages in the supply chain is certainly going to be challenging. However, in a world characterized by rampant risk, this may offer a sobering, albeit costlier than the JIT alternative.

3. CONCLUSION

The main objective of supply chain management is to provide the high quality products to the end consumers at the lowest possible cost. Supply chain management is the most critical function of an organization in today's global competitive environment. As the supply chain includes global organizations, the network become more complex and potentially brings a variety of risks such as Covid 19 pandemic. Due to the current pandemic, the materials management issue has become extremely critical for organization around the world. This paper discussed the classical approach of just-in-case inventory to safeguard the shortage of the materials to resilient the supply chain. The additional inventory cost using the JIC approach outweigh the cost of shortage in inventory which could include but not limited to the cost of unfinished product or work-in-process inventory.

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5. REFERENCES

[1] **Aggarwal, A.K. and Dave, D.S. (2018)** "An Artificial Intelligence Approach to Curtail the Bullwhip Effect in Supply Chains," *IUP Journal of Supply Chain Management*, Vol. 15, No. 4, pp.51-58.

[2] **Aggarwal, A. K. and Dave, D. S. (2019)** "A Review of Managing Risk in Supply Chain" *Sankhya Vignan – Peer Review Journal of Research and Readings in Applied Statistics*, NSV 15, No. 2, pp. 9-14.

[3] **Dave, D. S, Dotson, M. J., and Stoddard, J. E. (2018),** "Consumer Awareness of Supply Chain Flows in Relation to Consumer Perceptions of Value-added by Supply Chain Management," *International Journal of Logistics Systems and Management,* Vol. 31, No. 3, pp. 387-401.

[4] **Dave, D. S., Dotson, M. J., and Stoddard, J. E. (2016)**, "Material, Information, and Financial Flows in Supply Chain Management,' *Sankhya Vignan – Peer Review Journal of Research and Readings in Applied Statistics*, NSV 12, No. 2, pp. 9-17.

[5] **Kerr, D. V.and Houghton, L., (2010),** "Just in Time or Just in Case: A VCase Study on the Impact of Context in ERP Implementation, *Australian Journal of Information Systems.* Vol. 16, No. 2, pp. 5- 16.

[6] **L'abbe Wu, N. (1989),** "Understanding Production Systems through Human Simulation: Experiencing JIC (Just in case) JIT (Just in time) and OPT (Optimised Production Technology) Production Systems", *International Journal of Operations & Production Management*, Vol. 9 No. 1, pp. 27-34.

[7] **Martichenko, R. O. (2020),** "Post Covid-19 Crisis Supply Chain: A Time to Rise," White Paper, *LaenCor Supply Chain Group*.

[8] **Sahin, E. and Robinson, E. P. (2002),** "Flow Coordination and Information Sharing in Supply Chains: Review, Implications, and Directions for Future Research," *Decision Sciences*, Vol. 33, Issue 4, pp. 505-536.

[9] **Sheffi, Y. and Rice, J. B. (2005),** "A Supply Chain View of the Resilient Enterprise," *MIT Sloan Management Review*, Vol. 47, No. 1, pp. 41-48.

[10] **Stadtler, H (2005),** "Supply Chain Management and Advanced Planning - Basics, Overview and Challenges," *European Journal of Operational Research*, Vol. 163, No. 3, pp. 575-588.

[11] **Wisner, J.D.** *Operations Management: A Supply Chain Process Approach*, Sage Publications, Inc., 2017.

MANAGEMENT AND STATISTICS
RESEARCH ARTICLE

DESIGN AND CONDUCT OF COURSE WORK IN Ph.D. PROGRAM.

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ABSTRACT

This article discusses certain important issues related with study and coursework for Ph.D. programmes with special reference to universities and research institutions in India. Some active and iumportant suggestions are given that may be useful for r esearch work.

KEYWORDS

Assignment, Tutorials, Evaluation, Class Participation.

1. INTRODUCTION

The Ph.D. is probably the highest level of degree student can achieve that usually follows a master's degree in the current educational system. Pursuing quality Ph.D. is not a pleasant walk in the park. One should be passionate about doing it . It is once in a life time and therefore it calls for full time commitment. The student should have intrinsic love for research and should be well equipped with research methodology. Ideally It should be making singular contribution to the existing body of knowledge. The student has to ask a formidable question to himself/herself while pursuing Ph.D. , as to weather through his/her research work is he/she adding some dimension/s to his/her domain discipline. The answer to this question should sound very positive and affirmative. The original research work in any branch of knowledge immensely helps in nation's transformation into knowledge and skill economy.

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The course work is a vital part of any doctoral program. It sets the tone and direction for the dissertation phase of doctoral program. It intends to ensure that the student develops not only the breadth but also the depth in his/her area of concentration. It equips the student with the latest development in his/her domain including the analytical research tools and techniques. It should be mandatory for all students admitted to Ph.D. program .

The number of courses could be 3 to 4 or even more . According to the current UGC guidelines it should be 3, one of them being a course on Research Methodology that is common to all disciplines. But it could be even more. During this author's tenure(2010-2016) as chairperson of Doctoral Program in Management(DPM) at Nirma University , even for external Ph.D. students the course work was comprised of 6 courses each of 3 credirs—4 Bridge courses and 2 specialized courses .

The current plight as regards the conduct and design of course work in Ph.D. programs in the universities in India in general, is not much satisfying and encouraging, of course barring few exceptions. If you do a random check and an informal interaction with the Ph.D. candidates whenever and wherever you happen to meet them—be it in the sidelines of research workshop, research seminar, doctoral conference etc. ; you would immediately come to know as to how much unclear and ambiguous are they on the issues like the names of the courses, the components of the respective courses, the conduct of the course work, the duration of the course work completion, the evaluation criteria and their weightage etc. It is the sole responsibility of the respective supervisors and the respective Doctoral Committees or Research Progress Committees to see to that there is well structured and very well defined course work outline for the candidate . The course work design should be well near ideal and comprise of all the relevant issues related to the course work as described in the following sections. Any casual , apathetic and perfunctory approach in the conduct and design of the course work on the part of the supervisor would render the candidate baffled, bemused and nebulous.

2. Course Work Outline Format

The course work outline format suggested below would substantially serve the purpose of setting the stage and direction for the dissertation phase of a doctoral program.

1 . Course Description:

It is a brief and concise summary of the significant learning experience and the benefits from a course. It is an outcome based write up normally not exceeding 60 words that begins with the active verbs like demonstrate, design, create, analyze etc. It should be student- centric and not instructor- centric. It should be in full alignment with the outcomes identified in the rest of course outline.

2. Learning Outcomes:

Learning outcomes identify the student's takeaways from the course. It specifies what the student would be able to do or demonstrate at the completion of the course. The learning outcomes are different from course objectives . Course objectives convey as to what the instructor intends to accommodate in the course whereas learning outcomes define the breadth and depth of learning student is expected to achieve. It clearly communicates expectations to learners.

In framing the learning outcomes the vague verbs such as 'know', 'understand' should be avoided as they are not so easily measurable. Rather the instructors should follow Boolm's Taxonomy wherein B.S. Bloom (1) has generated action verbs under three domain –Cognitive, Psychomotor and Affective. The action verbs in Cognitive domain are like identify, describe, paraphrase, apply, analyze, assess etc. The sample action verbs used in Psychomotor domain are like detect, listen, conduct, observe, demonstrate, execute, produce etc. The sample action verbs under Affective domain are comply, conform, initiate, prefer, seek , act upon, advocate , exemplify , justify, support etc.

The number of learning outcomes should be between 5 to 7.

3. Pedagogy to be adopted by the instructor:

The pedagogy to be followed by the instructor should be clearly specified. The

conventional lecturing method fails to generate interaction amongst students and does not encourage them for raising the right and relevant questions. Therefore keeping lecturing at low key , several other teaching methods like group discussion, role play, case presentation and discussion, game based teaching like business simulation games and other didactic games , ungraded and graded quizzes, interactive sessions etc. can be employed in the classroom.

4. The course materials, Reference Books, Journals, Databases, Weblinks shoud be recommended by the supervisors.

5. Course work components:

A. It should comprise of a balanced mix of the 3 or 4 of the following components

- The doctoral scholar may be asked to attend some course allied to his/ her domain discipline and to his/her doctoral research topic, if at all offered in the current Master's program. He /she in that case should be complying with all the requirements of that course.
- Writing case/s related to his/her area of concentration; or preparing a detailed annotated bibliography on the topic of study.
- Developing a term paper on related topic
- Developing a working paper on the related topic
- Interactive tutorials
- Lab experience- hands on, simulation, demo etc.
- Relevant literature reviews with periodic discussion with supervisor
- Actual class room teaching for 8 to 10 sessions by the respective supervisor.
- Detailed Book reviews of at least 3 books.
- Any other component that supervisor thinks fit to incorporate such as seminar.

B. If the research is of qualitative nature where the philosophical worldview is that of

Interpretivism or social constructivism , the components of the course work could be the techniques like Ethnography(participant observation), Phenomenology,

Grounded Theory, Discourse Analysis, Narratives, Symbolic Interactionism etc.

6. Evaluation of Course work

The evaluation components in general could be as follows:

- Assignments
- Quizzes
- Interactive Tutorials
- Project Presentation
- Term End Written Examination
- Class Participation
- Presentation of assigned topics
- Detailed Book review of at least 3 books for a course/ review of research and experimentation

The Evaluation components for Domain specific courses could be ,more or less as follows:

a. If it is case based then, Case Writing, Case Teaching , Case Presenting Skills, Social Skills, Professional Skills, Conceptual Understanding etc. with respective weightage.

b. In technical courses for Hands on Simulated labs, it could be Design Skills, Social Skills, Professional Skills, conceptual understanding with respective weightage. Here also the component of written exam , could be incorporated with due weightage. In all above components candidate wise rankings / ratings / marks / Grades—whatever metrics the Supervisor prefers to adopt must be documented.

7. **The Evaluation Components with respective weightage to be considered in Ph.D.Course work**

The different components of evaluation shall be designed with utmost care by the supervisors. He /she may share orally or in writing his/her expectations from the doctoral students as regards different components The components like Assignments, quizzes, Interactive tutorials, class participation may have weightage between 10% to 15%; term paper/working paper presentation, literature review, preparing annotated

bibliography, project presentation/case presentation, detailed book review of at least 3 books for a course, review of research and experimentation (especially for technical courses) may have minimum 20% weightage.

Term –end written examination should be made compulsory with at least 30% weightage.

For the technical courses ,

i) Hands on Lab Experience —20% weightge

ii) Simulated Labs ,

It could be the assessment of Design skills, Social skills and conceptual understanding etc. ————20% weightage

iii) Survey ——15%

8. Time frame:

The approximate timeframe within which the course work is expected to be completed should be set by the supervisor. Such well structured course work outline would bring absolute clarity to the student about the kind of efforts he/she is required to put in to wade his/her way through the following phases of his/her dissertation that would ultimately culminate into an award of precious Ph. D. degree.

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Reference:

Bloom B.S., Englehart M.D., Furst E.J., Hill W.H., Krathvohi D.R.(1956), Taxonomy of Educational Objectives :The classification of educational goals, *Handbook 1:Cognitive Domain,*New York, David McKay Company Inc.

MANAGEMENT AND STATISTICS
ARTICLE

INVENTORY MANAGEMENT TRENDS : 2020 AND BEYOND

Jayesh R. Purohit[1]

ABSTRACT

Inventory management and technology – this is a match made on earth (writing 'heaven' here would have been a major exaggeration). Online & offline merger of everything – from inventory to customers to business operations to vendors – is the key. And it is happening across, quite religiously. **But what more to expect in this inventory world in 2020 & beyond?** Let us note a few.

KEYWORD

Big Data, IOT, RFID.

THE OMNIPRESENT (UNIVERSAL) CLOUD

Undoubtedly, inventory is the dearest asset of retail or wholesale businesses, be it small, medium or large sized. And real-time inventory visibility & tracking is always a big challenge, and a definite area to be perfected and updated over time. A system that has all data in one place, which is accessible to you in real-time and highly secured, is the right way out to solve major inventory issues. Cloud applications are hence replacing the on premise applications that are highly prone to errors and eat away a huge resource cost.

Cloud computing refers to storing and accessing data & programs over the Internet instead of computer's hard drive. The 'cloud' is a metaphor for the Internet.

While large-sized enterprises can afford a private cloud, subscription-based cloud models are a to-go-for thing for small & emerging businesses. Taking a leap forward

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for cost efficiency, operational swiftness and a robust bottom-line? Why not! A definite overhaul of inventory management systems through cloud migration by all size and forms of businesses is most prone to happening.

BIG DATA & THE THING THAT IS 'THE INTERNET OF THINGS (IOT)'

'Big data' and 'IoT' are different and hot terms, which go pretty much hand in hand.

Big Data represents massive amounts of human-generated data, which is a result of variety of sources – social media, transactions, enterprise content, emails, etc. The Internet of Things (IoT), on the other hand, turns things into smart objects or machines.

Imagine your products in warehouse or stores being chipped with tiny sensors and you can track its movement on your phone through internet. Sounds similar to controlling room AC temperature from your phone? Control is the word here! These sensors or devices are connected to the internet or each other to collect and transmit data. This information can become Big Data when it is combined with information from other sources, analytics of which can be used to device useful inferences and insights. IoT is seeping deep into **inventory management** operations like warehousing, shipping, retail stores, etc., helping businesses not

only react when they occur but predict and fix them beforehand. Tiny tags and embedded chips bolted into inventory racks will become a norm soon.

HYBRID WAREHOUSING – HYBRID SHIPPING

If you are in the e-commerce or retail business, you would know that warehouse management is a crucial part and an obvious cost center. You also must have often come across the term drop shipping. Drop shipping is an order fulfillment method that allows businesses to sell without owning the inventory. Instead of purchasing and storing the inventory in a warehouse, you partner with a third party, usually a wholesaler, distributor, or manufacturer to fulfill orders directly to your customer. While another model is the traditional warehousing and shipping. There are various pro & cons affixed to each model of shipping. But we see a growing trend of sellers adopting a hybrid approach where you can hold part of your inventory and get the

rest of it drop-shipped. This approach lets your customer reach grow multi-fold with you being able to offer a plethora of products, reduce your warehouse costs, and generate less or no headache.

What is to be warehoused or drop-shipped is a tricky plan and asks for a good market understanding. But going hybrid can save a significant amount of money that is wasted in under-stocking and over-stocking.

More and more sellers will be adopting this system, so that they ***store less, sell more.***

OMNI-CHANNEL INVENTORY CONTROL

Customers now are super customers. They demand instant quality, quantity & availability which strains sellers to deliver great value at bottom costs. They have learned to expect little conveniences like being able to go on your online store to look up whether a particular item is in stock at the store nearby and reserve or purchase it. As a seller, how if you are able to record a sale at one store and fulfill the transaction at a different store that has available inventory, for quicker fulfillment? Obviously, having such an omni-channel business is a serious accomplishment. But a successful one actually requires a major operational upheaval and a streamlined omni-channel inventory control.

It becomes a sort of mandate to reconcile your digital and physical inventory count, and to ensure that your stock data is up-to-date across channels. For customers, apart from availability and access, it is also very important that they find parity in prices & discounts across channels.

A customer will leave upset if he/she checks out your store for a gift to be sent to someone, and tries to book the same at your online counterpart for quicker fulfilment, but changes his/her mind seeing higher price in either of the channel. Hence an omni-channel inventory control platform is becoming a prerequisite.

RFID (RADIO-FREQUENCY IDENTIFICATION) UPRISING

More and more businesses are now going for RFID devices that enable accurate and quick tracking of products and their specifications in their facility.

Handheld devices that emit corresponding signals will connect with the chip

installed in the products to retrieve location, quantitative or qualitative data or any stock movement.

This is very important because overstocking can cause items (particularly perishable products) go bad, and under stocking can result in delayed shipping times and hence lost customers. Not just that, stock security can be assured and any theft can be tracked. The coming year will see extensive use of RFID across business types and sizes. And why just businesses, RFID technology seem to be now partnering with nature as well. RFID based tracking system is employed to prevent trees extinction and deforestation in few places in few parts world. This enables the detection & identification of cases of illegal logging of trees and hence preventing risks of species distinction and deforestation threats. Nature, after all, is a priceless inventory.

INVENTORY MANAGEMENT ON THE GO

Long time ago, we had apprehensions when we realized that we could shop online or book tickets in a few minutes. And now it seems a norm. From office work to daily communication (social media or email) to shopping to accessing any form of data – sleek tablets and smartphones are our facilitators. And so an obvious escalation of usage of mobile devices in business operations is universally expected and now accepted. Asset and inventory management software which previously catered to just desktops and equipment specifically designed for business operations, is now available for use as apps on our mobile devices. Employees are able to access, collect and analyse management data on their own personal devices, and simultaneously can take proactive inventory management measures.

The Bring Your Own Device (BYOD) trend has raised the standards and is slowly bound to become a norm in inventory management.

BLOCKCHAIN, THE SMART KEY

Blockchain is all over the internet and is quoted to be the most important technology invention, only after internet. It is a kind of revolution in data base and transaction management. Blockchain itself is a decentralized record of digital data or events of transaction that take place between two parties.

Many users may access, inspect, or add to the data, but cannot tamper

it, hence allowing high security and transparency of data and making it easier and safer for businesses to work together over the internet.

Now imagine of its potential to transform the inventory management. From conducting payment and audits to tracking inventory and assets, Blockchain technology will facilitate greater supply chain efficiency than ever before. Every time a product changes hands, the transaction can be documented, creating an indestructible history of the product, from manufacture to sale. This could radically reduce time delays, added costs, and human interventions error that plague transactions today. Users can set up 'smart contracts', which get fulfilled automatically when the necessary conditions are met.

WAREHOUSE GET THEIR ROBOTS

Robots might, very slowly & steadily, replace humans in the warehouses. Automation is already well-established in businesses across the world, but for most, it is limited to workflow automation in increasingly advanced warehouse management systems. The situation is changing with more and more MHE (Material Handling Equipment) manufacturers welcoming robots to their warehouses – for accuracy, to avoid spoilage and save human costs.

Robotic solutions offer the ability to introduce automation into data center operations without the call for any major structural revisions. The speed of businesses embracing robotics shall however be very slow, and very limited.

The real turning point in the warehouse robotics trend will arrive when technology vendors master the art of robotic picking, where robots are able to pick orders from conventional racking. Advancement in robotics warrant pretty deep attention, for this year and coming years.

CHANGE IS INEVITABLE, OBVIOUSLY.

And yes, change is the only constant, too. So it is always in the best advantage for everyone to adopt the changes and remain in the race. No doubt about that, right? The best thing businesses can do is to remain open to these new possibilities and keep their organization running as effortlessly as possible.

RESEARCH ARTICLE

COVID-19, ECONOMIC THEORIES AND INDIAN ECONOMY

Ranjan Gohil[(1)] and Pradeep Prajapati[(2)]

ABSTRACT

The present paper aims at examining and evaluating the socio – economic impacts on Indian economy in the presence of fiscal and monetary measures, the present relevance of the economic theories in the context Government actions during the lockdown periods because of COVID - 19 and accordingly to suggest some possible alternative policy measures with challenges emerged and its implications for the economic development of India, more particularly under the current and future epidemic situation of CORONA.

KEY WORDS:

Natural economic balance, Lockdown, Strong ordering form of preference, Social welfare, Economic growth, Fiscal and Monetary Measures, Macroeconomic stability, Supply side economics, self – reliance.

INTRODUCTION:

Though Indian economy was going through some serious socio – economic problems like lower of economic growth, reduction in employment, high inflation, huge corruption, terrorism, contraction of demand, severe poverty, inequalities, lack of confidence of Indian people in ecosystem, climate change and environmental issues etc. suddenly COVID – 19 attacked on Indian Economy, which would have very well expected serious socio – economic effects with huge deterioration of economic growth and economic imbalances.

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To overcome these effects of COVID – 19 crises to achieve economic balances there were two methods before the Indian Economy to correct the economic imbalances, that is, Automatic Adjustment Mechanism (though of **Adam Smith**) and Government Policy Measures (thought of **Keynes**). Automatic adjustment mechanism is one where government does not play any role and natural economic balance is achieved automatically through concerned economic variables, responsible for imbalances.

A classical economist **T R Malthus** propounded the theory of Demographic Transition and Population Explosion explaining how natural economic balance is achieved between the numbers of mouths i.e. demand for foods and supply of foods, considering the various factors such as immunity, efficiency, productivity, birth rates, density of population, dirty slums and unhygienic living slandered, epidemic diseases, death rates etc., but it takes a long period of time to correct the imbalance.

A modern economist **J M Keynes** says in this regard that "in the long run we all are dead", meaning thereby there should be some government policy measures to correct the imbalances in short run, as an alternative method of correcting economic balances.

To overcome the COVID – 19 crises some measures were initiated by Government from 25th March 2020 giving priorities to social welfare than economic growth, which reflected the strong ordering form of preference of the Government.

The Strong Ordering Form of Preference concept is given by the well known economist **Paul Samuelson** against Weak Ordering Form of Preference concept of economist **Hicks** to discuss the consumer behaviour in optimizing a particular goal of economic entity assuming an individual is rational. **Samuelson's** Revealed Preference Theory states that under the unitary income elasticity when an individual prefers commodity – A to commodity – B it never prefers commodity – B to commodity – A in any case.

It clearly seems that Union Government preferred social welfare (i.e. commodity - A) to economic growth (i.e. commodity - B) during the first three lockdown periods i.e. from 25th March 2020 to 14th April 2020, 15th April 2020 to 3rd May 2020 and 4th May to 17th May 2020 due to COVID - 19 to optimize the ultimate goal of saving human lives (social welfare) at the cost of economic growth. The words on definition of economics of well known economist **Alfred Marshal are worth remembering here that economics is meant for social welfare and not for nation's wealth.**

Wealth is an instrument to achieve social welfare.

To achieve the maximum social welfare the Union Government had initiated some Fiscal and Monetary measures for a certain period, as an interim injection. Some experts, researchers, thinkers, institutions and organisations are of the opinion through news, articles, discussions, talks, addresses, twits, webinars etc. that Indian economy is almost collapsed by all means because of the lockdowns due to COVID – 19, though some financial measures announced and it will take sufficiently long period of time to recover losses occurred thereof. Under the circumstances followings are the main amongst the other objectives of the present paper to test with;

MAJOR OBJECTIVES:

1. To examine and evaluate the socio – economic impacts on Indian economy during first three lockdown periods in the presence of fiscal and monetary measures.
2. To examine and evaluate the present relevance of the economic theories in the context Government actions during the lockdown periods. And;
3. To suggest some possible alternative policy measures with new challenges emerged, if any, and its implications for the economic development of India, more particularly under the epidemic situation of CORONA and thereafter too.

METHODOLOGY:

The authors relied only on the secondary sources – news published through print and released through electronic media and also personal academic knowledge of authors related to subject matter.

The paper, subsequently, takes up the examination and evaluation of the objectives set out in the present study, according to the authors' view points.

EXAMINATION AND EVALUATION OF THE OBJECTIVES:

Objective – 1: Socio – economic impacts;

To meet with COVID – 19 crises with an ultimate objective of achieving maximum social welfare the Union Government firstly announced the fiscal policy on 26th March 2020 consists of financial package of rupees 1.7 lakh crores for a certain period of time.

Under the Prime Minister Garib Kalyan yojana it was decided to distribute free wheat, rice with dal for next three months. And some amount of direct cash transfer to 20 crore Jan Dhan Accounts Holders. Also increased MGNREGA wage from Rs.182 to Rs. 220, decided Rs.1000 one time payments to widows and senior citizens, Rs. 2000 up to maximum of Rs. 6000 to the farmers etc. measures were initiated with certain conditions like social distancing, home quarantine, personal sanitising and hygiene etc.

And on 27th March 2020 Monetary Policy was announced by RBI reducing the Repo rate to 4.4 percent and reverse repo rate to 4 percent with some other measures.

Though there were above mentioned fiscal and monetary measures following are the main socio – economic impacts of the COVID – 19 on Indian Economy during first three lockdown periods;

1. Even before March 2020 because of foreign disinvestment and negative FPI and mutual funds in financial services, auto sector, consumer's staples, Information technology, energy and banking sectors Index of Industrial Production (IIP) was declined by 6.5 percent and production reduced by 40 percent of total production.
2. There is a gap found between income of the people salaried and middle class and their expenditures during lockdown periods. Around 40 percent of their income is spent and that is to only on grocery items and just to daily sustains life. And hence rest business and transaction are completely earth down.
3. Manufacturing, accommodation and food service i.e. hotels and motels, wholesale and retail trade, real estate, tourism and automobile sectors are totally collapsed. The question posed is about rise in rate of unemployment and heavy loss of share in GDP of these sectors.

   Just take an example of auto sector which provides a job to almost 4 crores of people. It contributes almost 8 percent in GDP and 11 percent in a tax collection. Now think that up to the end of third lockdown period not a single vehicle of any company was sold out what would be its impact on employment and income. The same is a case with other sectors when they are suffering from negative performances, such as;

   Cement minus 24.7 percent, natural gas minus 15.2 percent, steel minus 13 percent, fertilizer minus 11.1 percent, electricity minus 7.2 percent, crude

oil minus, minus 5.5 percent, refinery 0.5 percent, industry, manufacturing, construction, travel-tourism and accommodation i.e. hotels are completely collapsed.

4. Almost 90 to 92 percent of the total labourers are engaged with the unorganised sector in India, for which government does not take any social responsibilities. It is very pitiable to say that employments of almost all such labourers have totally gone.
5. Galloping Inflation is found in urban and cities in comparison to running inflation in villages as retailers have also started taking benefit of the conditions laid down to be followed strictly under lockdown periods.
6. Very severe price instability i.e. gap between the prices received by producers and farmers and prices paid by the end users i.e. consumers in almost all the necessary goods and glossary items, is found.

On the other hand Indian Economy could able to save daily millions of rupees for non consumption of petroleum products and lack of demand for precious commodities like gold, silver etc. of the people in general. But unfortunately people would not have had any benefit of it in terms of even reduction of prices of these products and items.

Under the aforesaid situation it is predicted by some national and international institutions and organisations like World Bank, International Monetary Fund, International Labour Organisation, MOODIs atleast for the remaining next months of the year 2020 after opening the lockdown periods that;

1. There would be a reduction in approximately 10.5 percent working hours because no work with the people as around 30 crores of people having full time jobs are jobless now, because of lockdowns. Not only that there is a severe uncertainty and strong threat of jobs for 43 crores people engaged with enterprises, businesses, self employments, start-ups etc.
2. There will be shortfall of Labour supply as labourers would not be ready come back from villages to urban and cities for their employment and livelihood.
3. There would be more deaths because of starvation than CORONA virus.
4. Cost of business trade would be increased.
5. **Economic growth rate would be zero or negative (- 2 percent) or very low (2.4 percent) as per different projections and hence there would**

be macroeconomic instability in Indian Economy.

It is clearly revealed from the above discussions that Indian Economy is failed to achieve even social welfare because it did not concentrate on the ultimate goal of the Macroeconomic Stability, which infect is the pre – condition of the economic development for any economy according to the economic theorists. Test of objective – 2 is material in this regard, as follow;

Objective – 2: Present relevance of economic theories;

As seen herein above that macroeconomic stability is the pre – condition of any economy, an attempt is made here below what is macroeconomic stability, how can it be achieved and whether the theory is relevant or not under the COVID – 19 crises Indian Economy.

Macroeconomic Stability is the first and foremost objective of good economic theory with the ultimate goals of (1) Internal Stability, refers to full employment or unemployment of not more than 2 to 3 percent per year and a rate of inflation of not more than 2 to 3 percent per year (2) External stability, refers to equilibrium in the balance of payments or a desired temporary disequilibrium (3) a reasonable rate of growth, and (4) an equitable distribution of income, to be achieved in any economy.

The concept was firstly explained by economists **Hicks and Henson** with the help of IS (investment and saving), LM (liquidity preference and supply of money) and FE (demand for and supply of foreign exchange) curves, popularly known as IS – LM – FE Model.

As per this model all markets (product market, labour market, money market and foreign exchange market) are said to be in equilibrium at a point where IS, LM and FE curves intersect each other at a particular interest rate and national income. If it is it can be said as internal as well as external stabilities (Macroeconomic Stability) are achieved at a time. If a nation deviates from this point of macroeconomic stability a particular set of economic problems like inflation or unemployment, excess liquidity or lack of liquidity, surplus in balance of payment or deficit etc. is created. To remove or to mitigate these economic problems, more specifically to control inflation and/ or to remove unemployment and hence to achieve macroeconomic stability economist **Keynes** has suggested Fiscal Policy and **Milton Friedman** suggested Monetary Policy.

As seen herein above very first time Fiscal and Monetary measures are not initiated for controlling inflation neither for reducing unemployment in Indian

Economy but for achieving the social welfare at the cost of economic growth. All these measures, are infect the "Supply Side Measures" as per the hypothesis of "Supply Side Economics" propounded by well known economists **Robert Boro, Robert Lucas and others followers of the then American President Ronald Regan.**

It is worth mentioning here that while suggesting fiscal policy measures **Keynes** was of the opinion that no such relief or package is to be offered which destroy the work efficiency and productivity of the people/beneficiaries. If there is no work to be taken from people ask them to dig and then ask them to level it again and then only pay. But no relief in form of cash or any free package is to be provided under the government measures, in case of circumstances arise. Unfortunately the same is also not observed in Indian Economy.

Considering aforesaid discussions authors come to the conclusion that whatever the financial measures initiated were for the first three lockdown periods are not found performed well for achieving the social welfare. On the contrary almost negligible overall economic growth rate and negative performances of almost all the sectors are observed in Indian Economy, as mentioned herein above and hence Government is compelled to drop the dreamt dream of social welfare only at the cost of economic growth i.e. approach of strong ordering form of preference and has to go for second thought i.e. to maintaining reasonable economic growth rate with maximum social welfare declaring fourth but liberalised lockdown period from 18th May 2020 to 31st May 2020, announcing a huge financial package of Rs. 20 lakh crores.

It is to be noted here that authors leave an exercise of socio - economic evaluation of such package for next generation of researchers in the subject matter as future scope of research.

The failure of Indian Economy and its doldrums arises may be because of not proper knowledge and understanding of and/or implementing of all the economic theories and thoughts of **Malthus, Paul Samuelson, Hick, Marshal, Keynes, Friedman, Boro and Lukas** etc., recalled in the present paper. Therefore what are the new challenges emerged before Indian Economy and what could be the possible alternate solution to meet with, is the need of the day. Accordingly authors suggest some policy measures with newly emerged challenges and its implications, as under;

Objective – 3: Major Challenges, Suggestions and Policy implications;

After examining and evaluating the effects of third lockdown period the Government announced fourth but liberalised lockdown with the dream of self-reliance

India, announcing the financial package of Rs. 20 lakh crores.

It is to be worth noted here that the announcement of these financial measures incorporates almost all sections of the society i.e. marginal farmers to very big farmers, micro and small scale industries to large industries and big houses, agriculture to tertiary sector, rural to urban, daily wage earners to entrepreneurs, last man of the society to well off, end users to producers and sellers, micro-financed activities to banks and financial institutions, and what not!

One believes or not but it is very true that all the objectives set out for Demonetisation, Goods and Serves Tax, Clean and Healthy India, Digital India, Skill and Make in India and of NITI Ayog too, are almost observed satisfied, during the lockdown periods. But at the same time some major challenges have emerged, which should be the prime concern of the Government to meet with them.

Hence authors suggest following few measures with newly emerged challenges and its implications;

1. Migration of labourers towards the villages i.e. reverse urbanisation, Price instability and Food insufficiency:

(A) On one hand a very serious problem of food insufficiency was already there in the world including India, leaded to MAL-NEUTRITION because of insufficient production of Cereals and Pulses which provide Calories and Protein accordingly, growth rate of output of agriculture was not stable in India and agricultural productivity was also very low. The higher growth rate was not achieved by technical change – seeds, water economization and soil reclamation – in agriculture. And now lockdowns would increase the burden of labourers on rural and agriculture because of reverse movements of labourers from urban and cities to villages.

Solution of a problem: To overcome these problems it is high time to re-think on Land Reforms – i.e. ownership of land so as to increase agricultural productivity and accordingly to have higher growth rate.

(B) A second and very burning problem is that "Price instability" – i.e. a huge gap between what farmers get for their produce and what end users pay for. This is basically because agriculture sector is treated as "resource releasing" sector, dirty role of "mediators", transportation problems, shortfall in supply and undue benefits taken by the whole sellers and retailers too. "RURBAN DEVELOPMET MODEL" i.e. co-existence of Rural and Urban

Development **(this term is coined very first time by the authors only)**, is only the possible alternative remedy for these problems.

Solution of a problem: The only change that is if the Agro – based and Agro-processing industries are established and developed in the rural areas there would a co-existence of Rural and Urban Development and hence ultimately Development of a Country as per this model and it would have positive implications, such as;

(1) Agricultural sector is treated as sick industry and accordingly all the benefits and relief is to be given to the agricultural sector. (2) The urban regions would get rid of its overcrowding due to development of new industries. (3) Development of industries in rural areas would lead to increase in employment, increase in demand for raw-material would act as incentive for farmers, basic infrastructure like roads, electricity, water, drainage, educational facilities, transportation, police station etc. would develop resulting in development of social infrastructures like hospitals, education institutions, markets, etc. in rural areas. (4) The development of Agro – based and Agro-processing industries in rural areas would generate demand for not only the agricultural raw material from primary sector but also ancillary goods and capital goods from the secondary sector. This would increase the production in urban areas as absorbing additional and the excess labour supply and hence rise in the income of rural population, which would create demand for consumer goods, which would again increase production of consumer goods too. (5) Overall employment would increase in the urban areas which would resolve the problem of disguised unemployment (an alternate term is given by **Karl Marx** as "Surplus Labour") , mitigate the present problem of urbanisation and future re – urbanisation and migration too. (5) Because of the mitigation of urbanisation and re- urbanisation problems financial and other burden on urban authorities would be reduced and accordingly urban areas would highly be facilitated.

Thus, this would decrease the problems faced by both rural and urban India and co-existence of Rural and Urban Development (Rurban Development) would possible, resultant ultimately higher the economic growth rate.

2. Industrial growth is stagnant and negative:

As we have observed that industrial growth is stagnant and negative because

of the negative performances of different sectors in India and to overcome the problem i.e. to increase the industrial growth it is highly needed to change the present structure of industrial sector, which again is a major challenge before Indian Economy.

On one hand because of monopolistic competition of MNCs consumer durables market was expanded and became larger and larger day by day, which have collapsed the markets for Indian industries, more particularly for small industries and hence small industries are died. And now under the lockdown periods Marginal, Small and medium Scale enterprises are totally collapsed.

Solution of a problem: Therefore modern and big Indian industries are to be established and to be entered into the market to compete with MNCs, which again is a challenge as it required huge investment with a surety of lower reward rate.

When there were PSUs it was in the hand of government which could increase the investment but now under the privatization era there are no tax incentives to the private industries and also they have to pay higher rate of interest if they invest for large and modern industries. And therefore private owners are unable to take risk, which created a situation of "CRONIC CAPITALISM" instead of "PURE CAPITALISM".

Under the circumstances only Start-up and Skill India Policies is the hope that can produce such entrepreneurs and skilled labours to compete with these World Players.

3. Outward looking Trade Policy:

The question is that, can outward looking Trade Policy be a perfect? It can be but if it is welfare oriented. In the present era of capitalism/ privatization trading is being done only on the basis of Profitability and that is only on necessity based and not for welfare objective.

Solution of a problem: To overcome this challenge there should be freedom of trading with qualitative control rather than complete free trade. For example, trading of medicines is to be allowed in the name of "Generic" and that is too in bulk only. And hazardous chemicals, which increase the pollution and have high costs, are not to be allowed.

4. International Capital Movement:

Because of the convertibility in capital account and free movement capital inflow already increased on hand and would likely to increase after opening of lockdown as there are many MNCs and big enterprises are waiting to enter and invest to have a benefit of collapsed India which leaded and would further lead lower rate of return on capital investment of the Indian Investors.

Solution of a problem: Therefore some incentives are necessarily to be given to the Indian investors against this uncontrolled and free movement of capital in India.

5. Fundamental Constitutional Rights:

In the present era of Chronic Capitalism and also because of government guideline to be followed under lockdown periods most of the people are not enjoying their Fundamental Constitutional Rights – freedom, justice, equity and dignity - ensured to them, justifiably.

Solution of a problem: For which Government has to perform its functions of Security (internal as well as external both), Welfare (socio-eco-politico etc.) and Development (personal, regional and sectoral) very effectively.

6. Health Issues:

Following are identified major research areas that need to be further explored and understood;

- Asthma, Respiratory Allergies, and Airway Diseases
- Cancer
- Cardiovascular Disease and Stroke
- Effects of Heat
- Food borne Diseases and Nutrition
- Human Developmental Effects
- Mental Health and Stress-Related Disorders
- Neurological Diseases and Disorders
- Vector borne and Zoonotic Diseases
- Waterborne Diseases
- Weather-Related Morbidity and Mortality

Other than COVID – 19 current and future estimates of chronic effects of some of the above mentioned health issues in India which are aggravated due to climate change, are as shown in following table;

Health Conditions	Current Estimates	Future Trends	Possible Influences of Climate Change
CANCER	APPROXIMATELY 1.093 MILLION NEW CASES WERE REGISTERED IN 2011	IT IS ESTIMATED THAT BY 2026 THE NUMBER WOULD INCREASE TO 1.869 MILLION	DUE TO CLIMATE CHANGE THERE IS MASSIVE URBANIZATION AND GLOBALIZATION LEADING TO CHANGE IN LIFE -STYLE AND HABITS WHICH AGGRAVATE THE CANCER CHANCES
DIABETIES	APPROX. 61 MILLION DIABETIC PATIENTS	ESTIMATED IS CROSSING THE MARK OF 100 MILLION BY 2030	IT INCREASES SENSITIVITY TO HEAT STRESS, MEDICATION AND DIETARY NEEDS MAY INCREASE VULNERABILITY DURING AND AFTER EXTREME WEATHER EVENTS
ASTHAMA	APPROX. 13 MILLION CASES WERE REGISTERED IN 2016	THE INCREASE IN ASTHMA CASES IS APPROX. 30% ANNUALLY .	**ASTHMA IS EXACERBATED BY** EXPOSURE TO AIR POLLUTION AFFECTED BY CHANGE IN TEMPERATURE , HUMIDITY AND WIND
MENTAL ILLNESS	APPROX. 28 MILLION IN 2013	APPROX. 38.1 MILLION IN 2025	MENTAL ILLNESS MAY IMPAIR RESPONSES TO EXTREME EVENTS LIKE HEAT STRESS.
VECTOR-BORN & ZOONOTIC DISEASES	MORE THAN 973 MILLION PERSONS WERE EXPOSED TO VECTOR-BORNE DISEASES IN 1998	THE ESTIMATES VARY A LOT DUE TO SEVERE FLUCTUATIONS IN THE CLIMATE CHANGE	DUE TO CLIMATE CHANGE THERE IS A COMBINED POSITIVE INFLUENCE OF TEMPERATURE AND HUMIDITY ON SURVIVAL AND DEVELOPMENT OF MOSQUITOES AND PARASITES ; RECENT EPIDEMIC OF MALARIA , CHIKUNGUNYA AND DENGUE .

Solution of a problem: The vicious circle of climate change has infect leaded to the alarming situation created by the effects of climate change and this serious intervention is needed by policy makers to come out of this circle and save humanity and attain a sustained growth.

CONCLUSION:

To summarise economic development does not depend on foreign capital but also on the important factors like human capital and institutional factors, as all the developed nations have not been developed through foreign capital but they have been developed on the basis of economic conditionality, attitudes, values, ethics, social and political institutions of the people, natural and human wealth and opportunities of trade with rest of the world. It is necessary to enhance efficiency and productivity of the domestic factors of the production to achieve ultimate goal of macroeconomic stability as per economic theorists and also an objective set out of self –reliance India in the fourth but liberalised lockdown period.

LIMITATIONS OF STUDY:

1. The thoughts and ideas in this present paper are purely on the basis of information gathered through daily news published and telecasted in print and electronic media accordingly related to the subject matter, and subject related academic knowledge of the authors.
2. A socio - economic evaluation of the financial packages announced for the fourth lockdown period is not done in the present paper.
3. Taking care of the guidelines declared by the central and state governments other objectives than socio – economic evaluation are not set out and accordingly not examine and evaluated in the present paper.

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REFERENCES:

[1] **Ahuja H. L (1979);** Advanced Economic Theory: Microeconomic Analysis, S. Chand & Company Ltd, New Delhi.

[2] **Gohil Ranjan (2019);** "RURBAN" Development: Policy and Perspective, A Seminar Proceeding on Socio – Economic Development of India: Requirements and Reality, Patan (NG).

[3] **Prajapati Pradeep, Ranjan Gohil (2018);** Effects of Climate Change on Human Health: A case Study with Reference to Gujarat State, *Ajanta: An International Multidisciplinary Quarterly Research Journal, Vol. VII, Issue IV, October – December – 2018.*

[4] **Pradeep Prajapati (2018);** Valedictory Lecture on Emerging New India: Issues and Challenges in two days National Seminar, School of Studies in Economics, Vikram University, Ujjain, March 22nd – 23th, 2018.

[5] **Vaish M. C (2002);** Macroeconomic Theory: Twelfth Revised Edition, Vikas Publishing House Pvt Ltd, New Delhi.

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RESEARCH ARTICLE

ADAPTIVE DESIGN CLINICAL TRIALS- OVERVIEW AND REGULATORY PERSPECTIVE

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ABSTRACT

New drug development is time consuming and expensive process. Recently, there has been lack of progress in the development of the novel compounds. Moreover, the attrition rate in clinical research is also on the rise. Fearing more stagnation, the regulatory released the critical path initiative and critical path opportunity highlighting the need of advancing innovative trial designs. One of the key innovations suggested was the adaptive design clinical trials, a method promoting the introduction of pre-specified modifications in the design or statistical procedures of an ongoing trail depending on the data generated from the concerned trial thus making trial more flexible. The adaptive design trials are proposed to boost clinical research by cutting on the cost and time factor. This paper covers overview, regulatory standpoint on the issues and acceptance on adaptive design methodologies in clinical trials.

KEY WORDS:

Adaptation, design, clinical trials, statistical analysis, regulatory perspective

1 INTRODUCTION

In last several decades, it is recognized that increasing spending of biomedical

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(2) This topic was presented in Indian Society of Clinical Research (ISCR), 13th Annual conference held at Mumbai on 24JAN2020.

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research does not reflect an increase of success rate of pharmaceutical development. The low success rate of pharmaceutical development could be due to the rapidly increasing costs and complexity leading to decreased willingness/ability to bring new molecules in research and development. Unacceptable level of attrition in the clinical stage of development are driving profound changes in the architecture, design and analysis of clinical trials. Moreover pharmaceutical companies have gradually realized that the classically structured clinical trial does not offer enough flexibility to make use of continuously emerging knowledge that is generated as the trial progresses. To bridge the gap between basic scientific research and medical product development, improved and innovative testing methods were drafted so as to ultimately improve the manner in which drugs are discovered, developed and brought into the market. One of the strong recommendation by regulatory agencies is to use the adaptive deign methods in clinical trials and use of the Bayesian approach in clinical research and development. The purpose of the clinical trial is give the investigator flexibility for identifying the optimal clinical benefit of the test treatment under study without undermining the validity and integrity of the intended study. Adaptive designs for clinical trials of drugs and biologics – draft guidance for industry was distributed for the comments during September 2018, final published guidance, November 2019 is available which is fairly detailed.

2 WHAT IS ADAPTIVE DESIGN CLINICAL TRIAL?

A clinical trial design that allows for prospectively planned modification to one or more aspect of the design and hypothesis based on the analysis of the accumulating data (using interim analysis) from subjects in the trial. A trial is called "Adaptive" if it allows modification of an essential design features (e.g., sample size, randomization ratio, number of treatment arms etc.), based on accumulating data from within that clinical trial.

Changes should be carried out without compromising the integrity of the clinical trials. For confirmatory trials full designs of adaptations needs to be pre-specified.

The overall purpose is to make clinical trials more flexible, efficient and fast. Due to the level of flexibility involved, these trial designs are also termed as "flexible designs."

Flexibility here does not mean that the trial can be modified at any time at will. The modification and adaptations needs to be pre-planned, pre-specified in the analysis plan and should be based on the data collected from the study itself.

As per the regulatory draft guidance of the FDA for industry on adaptive design clinical trials defines an adaptive design clinical trial as "a study that includes a prospectively planned opportunity for modification of one or more specified aspect of the study design and hypotheses based on analysis of data (usually interim data) from the patients in the study. Analyses of the accumulating study data are performed at pre-planned time points within the study, with or without formal statistical hypothesis testing.

The term prospective here means that the adaptation was planned before data were examined in an unblinded manner. Changes in the study design occurring after an interim analysis of the unblinded study data and those were not prospectively planned are not within the scope of the guidance. Moreover, study design aspects that are revised based on the information obtained entire from the source outside of the specific study are not considered adaptive deign, irrespective of the fact whether such adaptations were planned prospectively or occurred as a response to unanticipated external events. However, prospective study revisions are based on information obtained from both a study-external and study-internal source are considered adaptive designs.

An adaptation is referred to any change made in to the trial procedure and/

or statistical procedure during the conduct of a clinical trial. Trial procedures may be eligibility criteria, study dose, treatment duration, study endpoints, laboratory testing procedures, diagnostic procedures, criteria for evaluation and assessment of clinical responses. Statistical procedures includes randomization, study design, study hypotheses, sample size, data monitoring and interim analysis, statistical analysis and/or methods for data analysis.

3 ADAPTIVE DESIGNS OVERVIEW

Commonly considered adaptive design methods in clinical trials include an adaptive randomization design, a group sequential design, a sample size re-estimation design, a drop – the-loser design, an adaptive dose finding design, a biomarker-adaptive design, an adaptive treatment switching design, a hypothesis-adaptive design, and adaptive seamless phase II/III trial design, a multiple adaptive design etc.

Another way of classifying adaptive design clinical trials is by categorizing them under different rules. Allocation rules defines how the patient will be allocated to different arms in a trial and comprises response-adaptive randomization and covariate adaptive allocation. Sampling rules defines how many subjects will be sampled at the next stage and consist of sample size re-estimation design (both blinded and unblinded) and drop-the-lose design. Stopping rule defines when to stop the trial and consists of group sequential design and adaptive treatment-switching design and change the primary end-point or statistical method or patient population design. Sometimes, fifth rule is added consisting of multiple adaptations, also comprising adaptive seamless phase II/phase III design.

Type of Adaptations in clinical trial

The different types of adaptive designs and key details are depicted in the table below

Types of Adaptive Designs	Key Details
Adaptive randomization design	✓ Alterations in the randomization schedule is allowed. ✓ Treatment, Covariate and Response adaptive randomization.
Group sequential design	✓ Trial can be stopped prematurely if there are safety or efficacy issues and depending upon the results of the interim analysis. ✓ This may not be appropriate since it may not be able to control the overall type I error rate at the desired level of 5%, if there is a shift in the target patient population due to additional adaptations or protocol amendments.
Adaptations to Sample Size(Sample size re-estimation design)	✓ A sample size can be modified or re-estimated in this type of design based on the observed data at interim, which can be performed in either a blinding or unbinding fashion based on the criteria of treatment effect size, conditional power and/or reproducibility probability.
Drop the loser design	✓ The subjects detected to have received inferior treatments at the interim analysis can be dropped out, based on the findings of the interim analysis ✓ Additional treatment arms can also be added.
Hypothesis adaptive design	✓ Design allows modifications or changes in hypotheses based on interim analysis results and design is often finalized before database lock or prior to data unblinding. ✓ Some examples includ e the switch from a superiority hypothesis to a non - inferiority hypothesis and the switch between the primary trial endpoint and the secondary endpoints
Adaptive dose finding design	✓ Dose-finding design is often used in early -phase clinical development to identify the minimum effective dose and the maximum tolerable dose which is used to determine the dose level for the next phase clinical trials ✓ For the adaptive dose -finding design, the method of CRM [Continual reassessment method: A likelih ood approach] in conjunction with the Bayesian approach is usually considered ✓ The Bayesian approach was developed specifically to deal with new data as they come in and to update the probabilities under investigation. Instead of determining the likelihood that a drug's efficacy could have occurred by chance, a Bayesian trial will give a probability that the drug was effective.

Advantage of adaptive clinical trials

Key Area	Advantages
Statistical Efficiency	✓ Greater statistical power ✓ Same power with smaller sample size, permitting flexibility in analysis
Ethical Consideration	✓ Ability to stop trial early which is questionable to demonstrate effectiveness and can reduce the number of patients exposed to unnecessary risk
Improved understanding of Drug Effects, Compound value, NDA requirements	Possibility to answer broader questions ✓ Adaptive enrichment, Dose selection & seamless for phase IIb/III ✓ Increased chance of trial being positive, or increased chance of meeting efficacy criteria as per NDA requi rements ✓ Increase a compound's associated expected Net Present Value
Acceptability to Stake holders	✓ Flexibility is key and more acceptable by sponsors and patient pool.
Cost & Duration	✓ Cut cost of individual trial or whole program ✓ Cut duration of trial or NDA submission

Limitation of Adaptive Designs

- ✓ Methods required to avoid increasing chance of erroneous conclusions and introducing the estimation bias.
- ✓ All considerations needs to be pre-specified up to certain level which will allow adaptations, this needs high level of planning and understanding.
- ✓ Gain in efficiency on one side may result is loss on other side (Example: Increased sample size, complex analysis, still speculative from regulatory perspective, strong integrity and ethical considerations towards decision making etc.)
- ✓ Opportunity for gain may be limited via adaptation, due to important scientific consideration and constraints or in certain clinical settings.
- ✓ Challenges in interpretation and generalizing the results.

Challenges in the path of Adaptive Designs

- ✓ It is common to have 3 to 5 protocol amendments during the conduct of trial. The target population may have been shifted during the process at the end of the trial, the overall type-I error may not be controlled.
- ✓ Major adaptations of trial and/or statistical procedures of ongoing basis may result in a totally different trial that is incapable to address the clinical questions the trial intends to answer.
- ✓ Significant adaptations may introduce bias/variation to data collection as the trial continues and operational difficulties are also encountered.
- ✓ These trials commonly use Bayesian statistical approach, but this is computationally and logistically complex, and might not be feasible in all situation.
- ✓ The data monitoring committee needs to meet regularly and quickly.
- ✓ Adaptive designs needs computer-based simulations of clinical trials to develop the design and protocol, requiring more work force, it can also make logistics/ supplies difficult across the sites.
- ✓ Gains are more when follow-up is short relative to duration of enrolment. (e.g.

early predictor of final end point or some information is available based on early data points)

- ✓ Randomization needs to be done via interactive voice response (IVR) if arms needs to be dropped and design needs dose response adaptation.
- ✓ Changes should be planned in advance and pre-specified for confirmatory trials and for confirmatory trials unbiased estimates must be available.
- ✓ Adaptation should meet needs of the whole program.

Conventional clinical trial design vs. adaptive clinical trial design

The difference between conventional clinical trial design and adaptive clinical design is depicted in the table below. We witness clear advantage of adaptive design on the conventional design.

Key Aspects	Conventional clinical trials	Adaptive Designs
Design	Not Flexible	Flexible
Treatment Groups	Limited to 2, 3 or 4	Multiple doses
Hypothesis testing	Hypothesis as planned	Modification is allowed
Modifications	Needs protocol amendment	Pre-specified is allowed.
Phases	Phase I/II are well defined	Seamless for Phase II/III
Statistical Analysis	Use routine frequentist Statistical methods	Use complicated Bayesian approach or other methods
Organization	Simple	Complex requiring simulations
Interim Analysis	If planned, not routine	Regularly at intervals
Role of Independent DMC	More as planned or once trial is over	Proactive role throughout trial
Regulatory view	Well recognized	Still Speculative

4 REGULATORY PERSPECTIVE

FDA and EMEA are proactive in implementing the adaptive designs in clinical trial. Adaptations are encouraged in exploratory stages (i.e. in Phase I and Phase IIa), there are some disagreements in confirmatory Phase III studies, since prospective

adaptation after looking in to the data are always debatable and questionable to certain extent, and this again depends on how much changes are done during the trial on ongoing basis.

There are some questions which needs to be addressed by regulatory agencies/ authorities.

- ✓ What level of adaptation will be acceptable?
- ✓ What are the regulatory standards for the review and approval process of clinical data obtained from adaptive clinical trials with different levels of modifications?
- ✓ The clinical trial become a totally different clinical trial after the modifications for addressing the study objectives of the originally planned clinical trial?

Regulatory guidance is continuously evolving with inputs from regulators, industry experts, and academia experts. Joint workshop was organized by US and EU regulators, involving experts and stake holders. Future prospects of these adaptive designed clinical trials are encouraging for both industry and regulatory agencies as well as from the patients' perspective.

5 SPECIAL CONSIDERATIONS AND TOPICS AS PER THE REGULATORY GUIDANCE DOCUMENT

Simulation in Adaptive Design Planning

- ✓ Simulation plays vital role in planning and designing of trials
- ✓ Used to select number and timing of interim analyses
- ✓ Determine appropriate critical value of test statistics for declaring efficacy or futility
- ✓ Estimate trial operating characteristics and demonstrate these operating characteristics meet desired levels

Bayesian Adaptive Designs

- ✓ Use of predictive statistical modeling, possibly incorporating information external to a trial govern the timing and decision rules for interim analysis
- ✓ Use of assumed dose-response relationships to govern does escalation and selection
- ✓ Explicit borrowing information from external sources e.g. previous trial, natural

history studies, and registries, via informative prior distribution to improve the efficiency of a trial

- ✓ Use of posterior probability distribution to form trial success criteria

Adaptation in Time-to-Event settings

- ✓ Power is dependent on number of events rather than number of subjects, when primary end point is the time to occurrence of a certain event
- ✓ Sample size adjustments has purpose of modifying the number of events and, therefore, may take the form of modifying the number of subjects, length of the follow-up period for each subject or both
- ✓ Interim analyses in time-to-event settings utilize information on surrogate or immediate outcomes

Adaptations Based on a Potential Surrogate or Intermediate End point

- ✓ Most adaptive design rely on ongoing monitoring of the primary end point or end points.
- ✓ In case of potential surrogate or intermediate endpoint exists that is correlated with primary endpoint, and primary endpoint itself is difficult or slow to ascertain.

Secondary Endpoints

- ✓ Multiple analyses of the primary end point can inflate the Type I error probability and lead to biased estimation of treatment effects on that end point
- ✓ Most of the secondary endpoints in clinical trial are correlated with the primary end point and often very highly correlated, and Type I error probability inflation and biased estimation can also apply to any end point correlated with primary endpoint.

Safety Considerations

- ✓ Although the adaptive design clinical focuses on outcomes intended to demonstrate effectiveness, safety objectives also play critical role, sufficient information on safety should be available for studies that adapt on efficacy end point, to support the product approvals
- ✓ Trials with early stopping for strong evidence of effectiveness still needs to collect the sufficient safety data to allow for reliable benefit-risk evaluation of the investigational drug and to inform labeling.
- ✓ It is important to take in to account size of the safety data when planning the number, timing and stopping boundaries of interim analysis.

Adaptive Design in Early-Phase Exploratory Trials

- ✓ Exploratory trials do not generally have same regulatory expectations as trials intended to provide substantial evidence of effectiveness (e.g. choice of dose, regimen, population, concomitant treatments, or end points).
- ✓ Flaws in an exploratory multiple-dose comparison trial could lead to suboptimal dose selection for a subsequent confirmatory trial, with resultant failure to show effectiveness or a finding of unnecessary excessive toxicity.
- ✓ Following good principles of adaptive trial design for exploratory trial can decrease the risk of adversely affecting the development program.

Unplanned Design Changes Based on Comparative Interim Results

- ✓ When trial data are examined in comparative interim analysis, data analyses that were not prospectively planned as the basis for adaptation may unexpectedly appear to indicate that some specific design change is ethically important or might increase the potential for statistically significant final trial results. Such revisions based on non-prospectively planned analyses can create difficulty in controlling the Type I error probability and in interpreting the trial results.

Design Changes based on the Information from a Source External to the Trial

- ✓ Event that occur outside of an ongoing trial during the course of drug development programs may provide important new information relevant to the ongoing trial and may motivate the revision of trial design e.g. unexpected safety information arising from different study in different population, new information regarding disease pathophysiology or patient characterization that identifies disease subtypes, new inform on PK or PD responses to drug, or other information that might have led to different trial design)
- ✓ In case of serious safety concerns in large trials, revising the trial design may be critical to allowing the trial to continue.
- ✓ Practically it is very challenging to ensure that a decision to modify a trial was based entirely on external information except in cases where sponsor is completely blinded to comparative interim results. This is one reason why limitation of access to comparative interim results is very important.

Interaction with Regulatory

- ✓ The purpose and interactions between a trial sponsor and regulatory vary depending on the stage of development

- ✓ The increased complexity of some adaptive trials and uncertainties regarding their operating characteristics may warrant earlier and more extensive interactions than usual.
- ✓ Early development of drug regulatory review of trial protocol typically focuses on the safety of the trial participants rather than validity of the inference about pharmacology activity or efficacy.
- ✓ As resources allow regulatory may review exploratory protocols to consider the relevance of the information being gathered to guide the design of later trials. Regulatory will have a more extensive role later phases of development.
- ✓ Sponsors who have questions should seek regulatory feedback by requesting a meeting (or written response only) addressing those questions.
- ✓ Although regulatory should be advised during the course of a trial of any proposed unplanned changes to the trial design (usually via protocol amendments), the regulatory agencies will generally not involve in the prospectively planned adaptive decision making.
- ✓ It is responsibility of sponsor, typically through the use of an independent data monitoring committee (IDMC) designated to implement the adaptive design.
- ✓ Minutes of Meetings from the open sessions of monitoring committee may be requested by regulatory agencies during the ongoing trial, but minutes of closed sessions or any other communication or information about comparative interim results should be kept confidential until the conclusion of the trial, except in unusual circumstances where patient's safety is at risk.

Documentation Prior to Conducting an Adaptive Trial

To allow for a thorough evaluation, in addition to the typical components of a non-adaptive clinical trial protocol, statistical analysis plan etc., such as those discussed in ICH guidance E9 *Statistical Principles for Clinical Trials,* documentation submitted to agencies prior to initiation of an adaptive design trial should include following:

- ✓ A rationale for the selected design
- ✓ A detail description of the adaptation plan, including the anticipated number and timing of the IA, the specific aspects of design that may be modified, and

the rule that will be used to make adaptation decision.

- ✓ Role of bodies responsible for implementing the adaptive design, such as the DMC and/or the dedicated adaptation committee (as applicable)
- ✓ Pre-specification of the statistical methods to be used to produce interim results, guide adaptations decisions, software details for interim and final analysis. If novel or customer software is used then information should be submitted to FDA before the trial to ensure there is no ambiguity, the information might include computer code when applicable.

Documentation Prior to Conducting an Adaptive Trial

- ✓ Evaluation and discussion of the design, which should typically include Type I error probability, power expected, minimum and maximum sample size, bias of treatment effect estimates, coverage of confidence intervals etc., such evaluations might be achieved via analytical calculations and /or computer simulations.
- ✓ Appropriate details of literature references or poofs for the methodology should be submitted.
- ✓ In case when simulations are primary or sole technique for evaluating trial operations detailed simulation report should be submitted with all details (e.g. design, details on futility after first interim look, positive trial after increasing sample size, set of parameter configuration used for the simulation scenarios and justification of choices, iterations for each scenario and rationale for the number, simulation operating characteristics, simulation code and summary providing overall conclusion).

Evaluating and Reporting a completed trial

A marketing application to regulatory that relies on a trial with an adaptive design should include sufficient information and documentation to allow FDA to thoroughly review the results.

- ✓ All prospective plans, relevant committee charters (e.g. data monitoring committee (DMC), adaptation committee charter), supporting documents (literature references, programming code and a simulation report)
- ✓ Information on compliance with the planned adaptation rule, compliance with procedures outlined in the data access plan to maintain trial integrity
- ✓ Records of deliberations and participants for any interim discussions by any

committees involved in adaptive process (e.g. meeting minutes from closed and open DMC or adaptation committee meetings decision, minutes of meeting from steering or executive committee as applicable)

- ✓ Results of interim analysis or analysis used for adaptations
- ✓ Appropriate reporting of adaptive design and trial results.
- ✓ More limited information with summaries

6. SUMMARY

The paper highlights the overview of adaptive designs and regulatory perspective. Overall adaptive designs are impactful, when done ensuring implementation limits or avoids operational bias and restricts sponsor exposure to unblinded results.

Importance of planning the design to have flexibility, the details on methodologies, interaction and discussion between trial sponsor and regulatory agencies, data safety monitoring board (DSMB) to buy in the adaptive procedures etc. It is necessary to understand and address all implementation issues in order to gain most benefits from adaptive designs. These designs helps to reduce the time, cut cost or increase the chance of the success of drug during development process.

7. ACKNOWLEDGEMENT

I thank the referee for his comments for reviewing this article which has helped its revision.

8. REFERENCES

[1] Adaptive Designs for Clinical Trials of Drugs and Biologics, Guidance for Industry, U.S. Department of Health and Human Services Food and Drug Administration, Center of Drug Evaluation and Research (CDER), Center for Biologics Evaluation and Research (CBER), November 2019, Biostatistics

[2] **Rajiv Mahajan and Kapil Gupta.** Adaptive design clinical trials: Methodology, challenges and prospects. Indian Journal of Pharmacology 2010; 42(4):201-207.

[3] **Mey Wang, Ya-Chi Wu, Guei-Feng Tsai.** A Regulatory View of Adaptive Trail Design. J Farmos Med Assoc 2008; 107(12):S3-S8.

RESEARCH ARTICLE

MUTUALLY ORTHOGONAL LATIN SQUARE DESIGN FOR A MAGIC SQUARE OF SIZE 4X4

D. K. GHOSH*

ABSTRACT

This paper discusses interesting problems related with magic sauares with emphasis on mutually orthogonal latin square design. Discussion brought here is also presented by an illustration.

KEY WORDS

LSD, MOLSD, Magic Square

1. Introduction:

A **magic square** is a square grid (where n is the number of cells on each side) filled with distinct positive integers in the range 1 to n^2 such that each cell contains a different integer and the sum of the integers in each row, column and diagonal is equal. The sum is called the magic constant or magic sum of the magic square. A square grid with n cells on each side is said to have order n.

The mathematical study of magic squares typically deals with its construction, classification, and enumeration. Although a general method for producing all the magic squares of all orders do not exist. So far three general techniques have been discovered namely (i) bordering method (ii) making composite magic squares and (iii) adding two preliminary squares. There are also more specific strategies like the continuous enumeration method that reproduces specific patterns. The magic squares are generally classified according to their order *n* as odd if *n* is odd, evenly even (also referred

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to as “doubly even”) if $n = 4k$ (e.g. 4, 8, 12, and so on), oddly even (also known as “singly even”) if $n = 4k + 2$ (e.g. 6, 10, 14, and so on). This classification is based on different techniques required to construct odd, evenly even, and oddly even squares. Beside this, magic squares are also classified as associative magic squares, pan diagonal magic squares, most-perfect magic squares, and so on the basis of certain properties,. More challengingly, attempts have also been made to classify all the magic squares of a given order as transformations of a smaller set of squares. Except for *n* d” 5, the enumeration of higher order magic squares is still an open challenge. The enumeration of most-perfect magic squares of any order was only accomplished in the late 20th century.

In regard to magic sum, the problem of magic squares only requires the sum of each row, column and diagonal to be equal. It does not require the sum to be a particular value. Thus magic squares may contain negative integers; they are just variations by adding or multiplying a negative number to every positive integer in the original square. Magic squares composed of integers 1 , 2 , . . . , n^2 are also called normal magic squares, in the sense that there are non-normal magic squares whose integers are not restricted to positive1 , 2 , . . . , n^2. However, in some places, “magic squares” is used as a general term to cover both the normal and non-normal ones, especially when non-normal ones are under discussion.

Chinese being the first to discover the magic squares and leading by several centuries, the Chinese construction of the magic squares are much inferior compared to the Indian, Middle Eastern, or European construction. The high point of Chinese mathematics that deals with the magic squares seems to be the work of Yang Hui but even as a collection of older methods, his work is much more primitive, lacking general methods for constructing magic squares of any order, compared to a similar collection written around the same time by the Byzantine scholar Manuel Moschopoulos

The Japanese interest in magic square began after the work of Yang Hui’s *Suanfa* and Cheng Dawei’s *Suanfa tongzong* in the 17th century. Isomura Kittoku (1660) gave both odd and even ordered bordered magic squares as well as magic circles,

he also developed a general method for construction of bordered magic squares. Various magic squares and magic circles were also published by Nozawa Teicho(1666) in *Dokai-sho*, Sato Seiko(1666) in *Kongenki*, and Hosino Sanenobu(1673) in *Ko-ko-gen Sho*. Seki Takakazu's(1683) in his *Seven Books* (*Hojin Yensan*) devoted completely to magic squares and circles. This is the first Japanese book to give a general treatment of magic squares in which the algorithms for constructing odd, singly even and doubly even bordered magic squares are clearly described. Yueki Ando(1694, 1695) gave different methods to create the magic squares and displayed squares of order 3 to 30. Yoshizane Tanaka (1683) developed fourth-order magic cube. In the beginning of the 18th century, the Japanese mathematicians developed the methods to construct magic squares of arbitrary order. After this, Yamaji started the enumerating of the magic squares.

The 3×3 magic square first appears in India in *Gargasamhita* by Garga during 100 CE, who recommends its use to pacify the nine planets (*navagraha*). Vrnda (900 CE) introduced the first datable instance of 3×3 magic square in India which occur in a medical text *Siddhayog* which was prescribed to women in labor in order to have easy delivery. The oldest datable fourth order magic square in the world is found in an encyclopaedic work written by Varahamihira around 587 CE called Brhat Samhita.

Remark: The magic square is given as a matter of combinatorial design, and no magical characteristics are involved in it.

Albrecht Dürer (1514) introduced the construction of magic square design of size 4 x 4. Later several authors have developed the construction of magic square design of size 4 x 4. They selected the 16 numbers as natural number from 1 to 16. Construction of this magic square design was done by keeping some of the 16 numbers at certain fixed row and column and then put the remaining numbers according to require sequence. In this investigation we have discuss the construction of a magic square of size 4 x 4 using Mutually Orthogonal Latin square design of size 4 where 4 is power of the prime number. The difference between the two method

is that he considered sixteen natural numbers from1 to 16 while we decided to construct this magic square design with any four distinguished numbers such that this four numbers are written once in each row and once in each column so as to make total cell or entry as 16. We define certain terms before constructing the magic square of size 4 x 4.

1.1 Definition: We define here Magic Square design, Latin Square design, Orthogonal Latin Square design and Mutually Orthogonal Latin Square designs one by one.

1.1.1 Magic square: Let there are n rows and n columns. The n^2 cells are filled up with 1 to n^2 natural numbers. An n x n square is said to be magic square if sum of numbers in each row and each column along with in both diagonal matrix is a constant number. For an example take n = 4. So the sixteen natural numbers are 1, 2, 3, ..., 16. A magic square of size 4 x 4 is given by

1	15	14	4
12	6	7	9
8	10	11	5
13	3	2	16

One can check here that each row sum is thirty four, each column sum is thirty four. Similarly both the diagonal sum is thirty four. Several solutions of magic square design of size 4 x 4 can be constructed from the existing design by taking all possible combinations of rows and columns.

Remarks: However magic square design developed here are different from the magic square discussed in 1.1.1. We define Magic square design in the following manner:

Let there are n rows and n columns. The n2 cells are filled up with 1 to n distinct natural numbers. An n x n square is said to be magic square design if n numbers are written in n rows and n column. Further sum of numbers in each row and each column along with in both diagonal is a constant. For an example take n = 4 which are a, b, c, d. So the four natural numbers are written in each row and each column. A magic square design of size 4 x 4 is given by

a	b	c	d
b	c	d	a
c	d	a	b
d	a	b	c

1.1.2 Latin Square Design: A design is said to be Latin square design if n2 treatments are arranged in n rows and in n columns. Further n letters are arranged in that n rows and n columns such that each letter occurs once and only once in each row and in each column.

1.1.3 Orthogonal Latin Square Design: Two Latin square designs, say L1 and L2 are said to be orthogonal Latin square design if by imposing one Latin square design L1 over the other Latin square design L2 , each pair of Latin letter occurs once and only once in the n x n design.

1.1.4 Mutually Orthogonal Latin Square Design: Let us consider more than two Orthogonal Latin Square Designs. If all the orthogonal Latin square designs are pair wise orthogonal then such orthogonal Latin square designs are called Mutually Orthogonal Latin Square Designs.

Bose and Shrikhande(1960) and Bose et.al. (1960) introduced and discussed the methods of construction of mutually orthogonal Latin square design. Moreover they applied this design for the construction of several other designs also.

2. Construction of Magic square design of size 4 x 4.

Here we construct magic square design of size 4 x 4 by using Mutually Orthogonal Latin square design. Therefore first construct a Mutually Orthogonal Latin square design of size 4 then construct the Magic square design of size 4 x 4.

Let n = 4 where 4 is a non prime number. This non prime number is written in the form of power of the prime number such as 4 = 22 where 2 is a prime number and other 2 is a prime number as well as an integer. Let the elements of the Galois field GF(4 = 22) are 0, 1, ?, ?2. Moreover ?2 + ? + 1 is an irreducible polynomial function of Gf(4) where ? is the primitive element of GF(4). Using this irreducible polynomial function and primitive element ? we construct one Mutually Orthogonal

Latin square design and is shown in Table 2.1

Table - 2.1 One Mutually Orthogonal Latin square design of size 4

0	1	α	$\alpha + 1$
1	0	$\alpha+ 1$	α
α	$\alpha + 1$	0	1
$\alpha +1$	α	1	0

Since size of the Mutually Orthogonal Latin square design is 4 therefore there will be three Mutually Orthogonal Latin square designs of size 4. One Mutually Orthogonal Latin square design of size 4 is shown in Table 2.1. Remaining other two Mutually Orthogonal Latin square designs of size 4 are shown in Table 2.2 and Table 2.3 respectively.

Table - 2.2 Second Mutually Orthogonal Latin square design of size 4

0	1	α	$\alpha + 1$
α	$\alpha + 1$	0	1
$\alpha +1$	α	1	0
1	0	$\alpha + 1$	α

Table - 2.3 Third Mutually Orthogonal Latin square design of size 4

0	1	?	$\alpha + 1$
$\alpha +1$	α	1	0
1	0	$\alpha + 1$	α
α	$\alpha + 1$	0	1

From Table - 2.1 we can observe that each of the four rows and four columns contain the entire four element 0, 1, α and α +1 once and only once. Therefore each row sum and each column sum is $(0 + 1 + \alpha + \alpha + 1)$, a constant number. This is not true for both the diagonal matrix. For the front diagonal all diagonal elements are same as 0 where as for opposite diagonal all the diagonal elements are same as (α +1).Therefore sum of diagonal elements are not same as those of row sum and column sum.

From Table - 2.2 and Table - 2.3 we can verify that each of the four rows

and four columns contain the entire four element 0, 1, α and α +1 once and only once. Therefore each row sum and each column sum is (0 + 1 + α + α + 1), a constant number. This is also true for both the diagonal matrix.

Now we construct Magic square design using Table - 2.2 and Table - 2.3 in the following way. Consider any four distinct numbers. These four distinct numbers will represent 0, 1, α and α + 1. Write these numbers at the respective position of 0, 1, α and α + 1 in each row and in each column. This provides us two solutions of Magic square design of size 4 x 4.

3. Example : Construct Magic Square design of size 4 x 4 with the following four distinct numbers 5, 28, 245, 415.

Solutions: Let 0 represents 5, 1 represents 28, α represents 245 and (α + 1) represents 415. Now replacing 0, 1, α and α + 1 by 5, 28, 245 and 415 respectively in the corresponding rows and columns of Table -2.2 and Table - 2.3, we obtain Magic square designs. These Magic square designs are shown in Table - 2.4 and Table - 2.5.

Table - 2.4 Second Mutually Orthogonal Latin square design of size 4

5	28	245	415
245	415	5	28
415	245	28	5
28	5	415	245

Table - 2.5 Third Mutually Orthogonal Latin square design of size 4

5	28	245	415
415	245	28	5
28	5	415	245
245	415	5	28

We verify that sum of each row, each column and both diagonal elements is 693.

Remark 1: We can not construct Magic square design of size 4 x 4 from Table - 2.1 because sum of elements of each row and each column are same but sum

of diagonal elements are not same.

Remark 2: Several solutions of Magic square design of size 4 x 4 can be developed by changing position of all possible combinations of row and column form table - 2.4 and Table - 2.5. We showed here two of them in Table - 2.6 and Table - 2.7.

Table - 2.6. Magic square from Table - 2.4

5	245	415	28
28	415	245	5
245	5	28	415
415	28	5	245

Table - 2.7. Magic square from Table - 2.5

5	415	28	245
28	245	5	415
245	28	415	5
415	5	245	28

4. Applications of Magic square:

(a) The magic square is constructed for the purpose of making perfumes using 4 substances selected from 16 different substances. Each cell of the square represents a particular ingredient, while the number in the cell represents the proportion of the associated ingredient, such that the mixture of any four combinations of ingredients along the columns, rows, diagonals, and so on, gives the total volume of the mixture to be 18.

(b) Magic square design is applicable for solving combinatorial problem.

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6. References:

[1] **Hosino Sanenobu(1673)** Magic square, Wikipedia, the free encyclopedia

[2] **Isomura Kittoku (1660)** Magic square, Wikipedia, the free encyclopedia

[3] **Manuel Moschopoulos Magic square**, Wikipedia, the free encyclopedia

[4] **Manuel Moschopoulos Magic square,** Wikipedia, the free encyclopedia, Google.

[5] **Magic cube with Dürer's square Ali Skalli's magic squares and magic cubes,** Google.

[6] **Magic Squares and Cubes (2nd ed.).** Open Court Publishing Company. pp. 124-126, Google.

[7] **Nozawa Teicho(1666) Magic square,** Wikipedia, the free encyclopedia, Google.

[8] **Oshizane Tanaka (1683) Magic square,** Wikipedia, the free encyclopedia, Google.

[9] **R. C. Bose, I. M. Chakravarti and D. E. Knuth (1960).** On method of constructing sets of Mutually Orthogonal Latin square using a Computer, Technometrics, 2, 4, 507 - 516.

[10] **R. C. Bose and S. S. Shrikhande (1960).** On construction of sets of Mutually Orthogonal Latin square and falsity of conjecture of Euler, Transactions of the American athematical Society , Vol. 95, No. 2 (May, 1960), pp. 191-209.

[11] **Sato Seiko(1666) Magic square,** Wikipedia, the free encyclopedia, Google.

[12] **Seki Takakazu's(1683) Magic square,** Wikipedia, the free encyclopedia, Google.

[13] **Vrnda (900 CE) Magic square,** Wikipedia, the free encyclopedia, Google.

[14] **Yang Hui, Magic square,** Wikipedia, the free encyclopedia, Google.

[15] **Yueki Ando(1694, 1695) Magic square,** Wikipedia, the free encyclopedia, Google.

RESEARCH ARTICLE

IMPACT OF MARKETING EXPENSES ON NET INCOME OF MICROSOFT COMPANY.

Sanjay G. Raval[1] and Vernal R. Damor[2]

ABSTRACT

In corporate world marketing strategies of a company can change its market position in the corporate world, which increases the brand recognition of the company. Net income of any company is partially influenced by the marketing efforts done by that company to increase its growth. Thus, one can state that there is significant impact of marketing expenses on the net income of a company. In this paper an attempt is done to understand such aspect for marketing expense and net income for Microsoft company based upon its data for years from 2000 to 2019. Statistical analysis is used to validate such impact of marketing expense on net income of Microsoft company.

KEY WORDS

PRIOR ANALYSIS, MARKETING, MODEL BUILDING, REGRESSION

1. INTRODUCTION

Professionals working in a corporate firm seek to get attention of the customers through marketing for selling their products. Marketing is done in every type of corporate firm through different media. Since last some years marketing through digital media has expanded in corporate world medium such as- social media, mobile

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advertisement, TV advertisement etc. are lately growing in the market for marketing purpose.For any product it may include different types of promotional activities such as celebrity endorsements, discount packages, catchy design of the products, media exposure etc. Marketing for any product makes the use of four P's: **Product, Price, Place, Promotion**.

Product: Marketers need to know which type of product is being sold and how their product is different from the product of other competitors.

Price: At what price the company should sell its product after considering their unit price, marketing expense, distribution expense, operational expense etc.

Place: Marketers need to understand the market and then decide through which channel their product should be sold. Different channels include physical store, online store or both the channels.

Promotion: Marketers should know which type of promotional activities can increase the growth of a company. Promotional activities such as sponsorship, direct marketing, banners, online advertisements etc are being carried out.

In present study considering the different media of marketing in the corporate firms the study is carried out for Marketing expense and Net Income of the corporate firm. The corporate firm taken into consideration for the study is Microsoft company. Microsoft was founded in 1975 by Bill Gates. As we all know that Microsoft is in the business of large number of products and services which give a better competition to other companies. Microsoft best acquisition strategy is to take over its competitors. Nokia, skype, Visio, Navision are some of the companies that Microsoft has been taken over by its acquisition strategy. The closest competitor of Microsoft i.e. Apple also, uses the operating system of Microsoft.

Microsoft also uses different marketing strategies through different channels for making its products and services available to the customers. Microsoft provides its product and services to the large amount of the customers by different networks such as retail outlets, e-commerce sites, exclusive showrooms, service centres etc. Microsoft is also involved in different campaigns like "Get the facts", "scroogled" etc. for

increasing its brand value. Microsoft uses different analytical strategies to study its marketing techniques such as **SWOT, PESTEL, VALUE CHAIN ANALYSIS,** etc.

2. METHODOLOGY

PRIOR ANALYSIS

The data from the years 2000 to 2019 for variables like Marketing Expenses and Net Income have been taken into consideration for the analysis. Prior analysis has been done by finding Fixed Base Indices (2000 is considered as the Base year) through which one can find the Annual Growth Rate of the corporation which gives the prior information regarding the growth structure of the corporation.

MODEL BUILDING APPROACH

Different econometric models may be found to be suitable for our analysis. Data from the years 2000 – 2019 have been collected and the variables considered for the analysis are marketing expenses and net income of the Microsoft company.

Let us define,

X= Marketing Expense (in Million $)

Y= Net Income (in Million $)

For this study, we propose log-linear(semi log) model as the econometric model which may be suitable for our analysis.

LOG – LINEAR MODEL

$\text{LOG } Y = \alpha + \beta X + U$

Here logarithm is considered with the base value $e \sim 2.7183$

α = Intercept term

β = Slope coefficient

U = Disturbance term

We can estimate the parameters α and β under usual normality assumptions using OLS method and also apply routine testing procedures including ANOVA using EXCEL.

3. DATA SOURCE

Relevant data considered in the study for the analysis of variables such as marketing expense and net income have been collected from the financial reports provided by the Microsoft company. The data considered for the study are taken for the years 2000 – 2019.

4. DATA ANALYSIS

Source: Financial reports of Microsoft company

Table 1.1

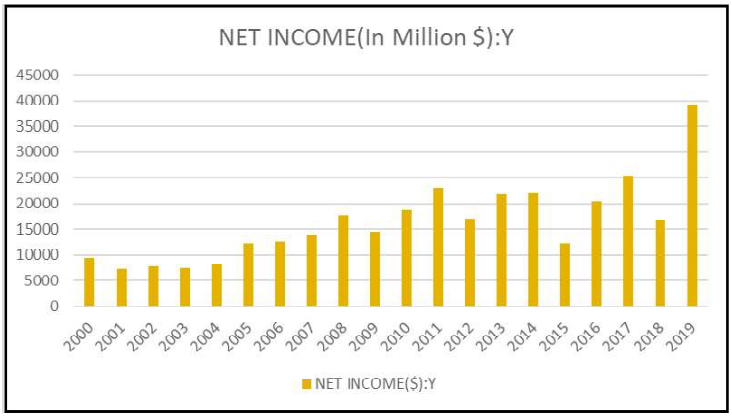
YEAR	NET INCOME : Y (In Million $)	MARKETING EXPENSE:X (In Million $)
2000	9421	4468
2001	7346	5888
2002	7829	6252
2003	7531	7562
2004	8168	8309
2005	12254	8563
2006	12599	9818
2007	14065	11455
2008	17681	13260
2009	14569	12879
2010	18760	13214
2011	23150	13940
2012	16978	13857
2013	21863	15276
2014	22074	15811
2015	12193	15713
2016	20539	14697
2017	25489	15461
2018	16571	17469
2019	39240	18213

Fixed base data for marketing expense		
Table 1.2		
YEAR	**FIXED BASE INDEX:X**	**%AGR** $=\left(\frac{\text{Current year value - Previous year value}}{\text{Previous year value}}\right)*100$
2000	100	
2001	131.7815577	31.78156
2002	139.9283796	6.182065
2003	169.2479857	20.95329
2004	185.9668756	9.878339
2005	191.6517457	3.056926
2006	219.740376	14.65608
2007	256.3786929	16.67346
2008	296.7770815	15.75731
2009	288.2497762	-2.8733
2010	295.747538	2.601134
2011	311.996419	5.494173
2012	310.1387645	-0.59541
2013	341.8979409	10.24031
2014	353.8719785	3.502226
2015	351.6786034	-0.61982
2016	328.9391226	-6.46598
2017	346.038496	5.19834
2018	390.9803044	12.98752
2019	407.6320501	4.258973
		%AAGR = 8.035115

Fixed base data for net income		
Table 1.3		
YEAR	**FIXED BASE INDEX: Y**	**%AGR** $=\left(\frac{\text{Current year value - Previous year value}}{\text{Previous year value}}\right)*100$
2000	100	
2001	77.97473729	-22.0253
2002	83.10158157	6.575007
2003	79.93843541	-3.80636
2004	86.6999257	8.458372
2005	130.0711177	50.02449
2006	133.7331493	2.815407
2007	149.2941301	11.63584
2008	187.6764675	25.70921
2009	154.6438807	-17.6008
2010	199.1296041	28.76656
2011	245.7276298	23.40085
2012	180.2144146	-26.6609
2013	232.0666596	28.77253
2014	234.3063369	0.965101
2015	129.4236281	-44.7631
2016	218.0129498	68.44911
2017	270.5551428	24.10049
2018	175.8942787	-34.9876
2019	416.5162934	136.7992
		%AAGR = 14.03306

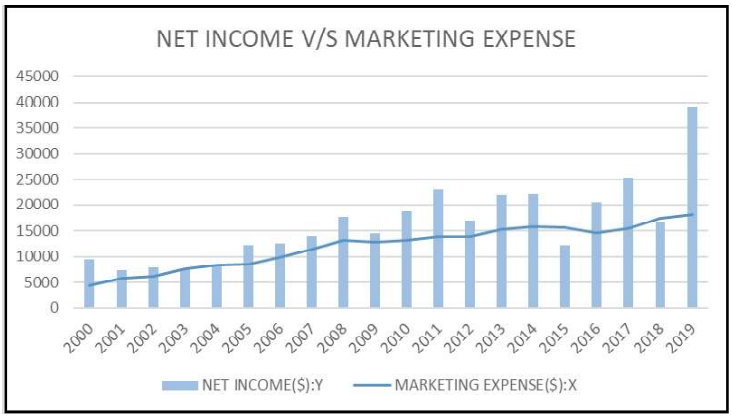
5. GRAPHICAL REPRESENTATION

Graph 1.1



Graph 1.2

Graph 1.3



INTERPRETATION

From the above graphs we can observe that as marketing expense increases, the net income also increases and vice versa. This suggests that there may be some sort of association between marketing expense and net income of Microsoft company.

6. REGRESSION MODEL

Table 1.4

Model: LOG $\hat{Y} = \hat{\alpha} + \hat{\beta}X + U$				
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
α	9.7477E-05	0.169559483	49.69577	1.01161E-20
β	8.426389602	1.33102E-05	7.323497	8.42334E-07
R Square = 0.748721278				
F Statistic = 53.63360221**				
p-value = 8.42E-07				

From the above analysis we may conclude that since R Square is 0.7487 about 74.87 % of the variation is explained by the model. R Square and regression coefficients are found to be highly significant. Hence, this suggested semi log model may be considered to be appropriate for our data analysis.

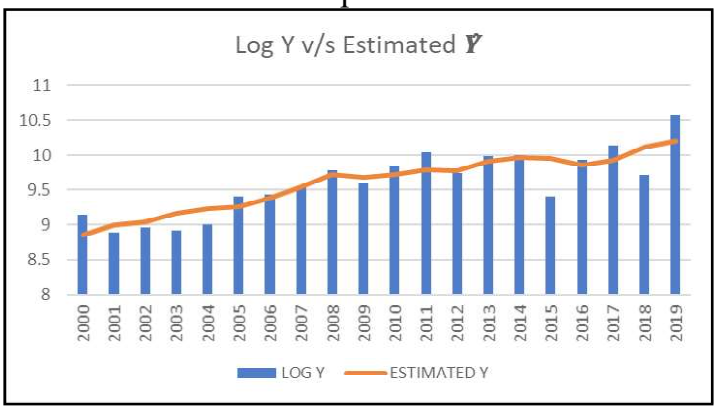
ESTIMATED INCOME

On the basis of the above fitted model the estimates for income are obtained which are given table 1.5 below.

Table 1.5

YEAR	LOG Y	ESTIMATED LOG
2000	9.150697	8.861916761
2001	8.901911	9.000334077
2002	8.96559	9.035815699
2003	8.926783	9.163510546
2004	9.007979	9.236325853
2005	9.413608	9.261085006
2006	9.441373	9.38341862
2007	9.551445	9.542988441
2008	9.780246	9.718934395
2009	9.586651	9.681795664
2010	9.839482	9.714450454
2011	10.04975	9.785218743
2012	9.739674	9.777128154
2013	9.992551	9.915447992
2014	10.00216	9.967598178
2015	9.408617	9.958045434
2016	9.930081	9.859008819
2017	10.146	9.933481234
2018	9.715409	10.12921502
2019	10.57745	10.20173789

Graph 1.4



7. CONCLUSIONS

- From the above graphs we can observe that there is some sort of association between marketing expenses and net income for the Microsoft company.
- For the given data log linear model is best fitted. Also, by Annual Growth Rate we can conclude that by spending minimum amount of marketing expenses the corporate can improve its Net Income. i.e. from table 1.3 we can say that, Microsoft company can improve its Net Income by 14.03306% by increasing 8.035115% of marketing expenditure every year.
- The above fitted model may be used for Net Income projection for future years if advertising expenditures are known.

8. ACKNOWLEDGEMENT

We thank the referee for his valuable comments and suggestions to revise this paper.

9. REFERENCES

[1] **Annual reports of Microsoft company,** https://www.microsoft.com/en-us/Investor/annual-reports.aspx

[2] **Damodar N. Gujarati, Dawn C. Porter (2009)** Basic Econometrics, 5th Edition, McGraw-Hill Irwin

[3] **Jack Johnston, John Dinardo (1997)** Econometrics Methods, 4th Edition, McGraw-Hill Irwin

[4] **Johnston (1984),** Econometric Methods, McGraw-Hill Irwin

[5] **Pulak Chakravarty (2009)** Quantitavive Methods for Management and Economics, Himalaya Publising House

REVIEW ARTICLE

STATISTICAL ANALYSIS IN CLINICAL TRIALS - (II)

Pinakin R. Jani*

ABSTRACT

This paper is in continuation to Sankhya Vignan (NSV15) Dec.2019, pg45-64, STATISTICAL METHODS IN CLINICAL TRIALS – (I), introduction and basics on statistical methods applied in clinical trials. We have made an effort to highlight topics on hypothesis testing, significance level, one tailed and two tailed tests, p-value, interim analysis, data collection, statistical summarization etc. The details will help the beginners to understand the concepts and application in clinical trial.

KEYWORDS:

Hypothesis testing, p-value, significance level, sample size, interim analysis.

1. INTRODUCTION

The paper highlights the important details on clinical trials, which includes hypothesis testing, significance levels, power, p-values, and example of the difference between one and two sided tests, the details towards sample size computation and the effect of multiple testing on significance level including interim analyses.

2. HYPOTHESIS TESTING

Significance Levels

In clinical trials when setting up hypothesis testing, an erroneous conclusion is made if the null hypothesis is rejected when it is really true. This error is called Type I error, and its probability is denoted by alpha (α), which is known as the "significance level" of the test. The rejection region is selected based on pre-determined value for α, usually a small value as 0.05. This means that there is only a 5% chance of rejecting a true null hypothesis.

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For example, administration of a drug was suspected to cause increase in HDL cholesterol levels in adult makes, a population known to have an HDL mean of 40mg/ dL during a clinical study via laboratory measurement. To test this, the null and alternative hypothesis are asset as

H_0: μ= 40 vs. H_1: μ > 40, where μ represents the population mean HDL cholesterol in all the patients who might quality to receive the drug, be a part of clinical trial and testing lab/facility.

A sample of the n patients treated with drug is observed as per the planned duration, and their HDL cholesterol levels are measured.

The Z-test is based on the standards normal distribution and compound from the sample mean (x) is chosen as the test statistics. Accordingly to the Central Limit Theorem, mean has normal distribution with mean μ and standard error σ/sqrt (n).

Z= x - μ/ σ/sqrt (n) has standard normal distribution. The null hypothesis would be contradicted if sample mean x is much greater than the known mean 40. The decision rule is to reject H_0 in favor of H_A when the test statistics is too large, compound under the assumption that H_0 is true.

Z_0= x - 40/ σ/sqrt (n), the rejection region is Z_0>c, where c is selected according to the chosen significance level α, that is

α = Pr (reject H_0 when H_0 is true) =Pr (Z_0>c)

The crucial value, c, can be denoted by Z_α, which is found from widely available tables of the probabilities for the standard normal distribution. For α =0.05, Z_α=1.645.

Suppose that previous laboratory testing at the study laboratory established a mean HDL cholesterol level of 40 mg/dL with standard deviation of σ=15 mg/dL. A current sample of 100 patients in sample mean of 43 mg/dL, the Z test summary is shown as below

Null hypothesis: H_0: μ=40 mg/dL

Alt. hypothesis: H_A: μ>40 mg/dL

Test statistics: Z= x - μ/ [σ/sqrt (n)] = 48-40/[15/sqrt (100)] =5.33

Rejection region: Reject H_0 if Z_0 > 1.645 at significance level α =0.05

Conclusion: Because 5.33>1.645, reject H_0, sufficient evidence exist to indicate an increase in mean HDL cholesterol level.

Power

Accepting the null hypothesis when it is not true is a second type of error

that can occur when testing a hypothesis. This is known as Type II error and has probability β.

For a given test, β is partially determined by the choice of α, ideally both α and β would be small. However, in general, there is an inverse relationship between α and β for a fixed sample size, n. Decreasing α (the probability of a Type I error), increase β (the probability of a Type II error) and, if taken too far, tends to render the powerless in its ability to detect the real difference from the null hypothesis. The power of the test is defined by (1- β), the probability of rejecting the null hypothesis when it not true. For the fixed significance level α, the sample size will determine β which is power of the test. Note that β is not only a function of the significance level and the sample size, but also value of the alternative hypothesis. They type II error probability is,

β =Pr (accept H_0, when H_A is true) = Pr (Z_0 d" 1.645, when μ > 40), which will differ for each alternative value of μ (> 40).

One-Tailed and Two-Tailed Tests

The form of the alternative hypothesis determines whether the test is a one or two tailed test. The HDL cholesterol example is a one tailed test because the alternative hypothesis is designed in one direction to observe and measure HDL greater than 40 mg/dL (i.e. H_A: μ>40 mg/dL). The two tailed alternative mean values would be specified as H_A: μ ‘“ 40 mg/dL, which indicates the interest in alternative values of the mean either greater or less than 40 mg/dL.

The rejection region of the two tailed Z-test would include both very large and very small values of the test statistics. For a significance level of α, you reject H_0 in favor of the two tailed alternative if $Z_0>Z_{\alpha/2}$ or $Z_0>-Z_{\alpha/2}$. For α =0.05, α/2 = 0.025 in each tail, of the normal distribution, obtaining $Z_{0.025}$=1.96 as the critical value for rejection from the normal distribution. The rejection region for the two tailed Z-test when α =0.05 is $|Z_0|>1.96$ (i.e., $Z_0>1.96$ or $Z_0>-1.96$) due to symmetry of the normal distribution. When the distribution of the test statistics is not symmetric, the relationship between one tail and two tailed test is more complex.

P-value

Formally, the conclusion of a statistical hypothesis test is to ‘reject’ or not to ‘reject’ the null hypothesis at pre-set significance level. Another way to describe is level of significance of any test or experiment is with its p-value. P-value is the

actual probability of obtaining the calculated test statistics or a value in a more extreme part of the rejection region, when H_0 is true.

If the probability distribution of the test statistics is symmetric, the p-value that corresponds to a two tailed test can be dived by 2, to obtain the p-value corresponding to the one tailed test. This is true for the Z-test, which has the standard normal distribution, and for the t-test which has the Student t-distribution, both of which are symmetrically distributed about 0.

Usually in clinical studies, the pre-set significance level is set to 5% (i.e. 0.05). The results of a statistical test are often described as significant when p-value of the test is less than 0.05, while it is described as "highly significant" when very small p-values (such as $p< 0.01$ or $p<0.001$ etc.) are obtained.

Sample Size Determination

Sample size is very critical in the clinical trial, it is determined from the desired power of the test, the significance level , the measurement of the variability, and the stated alternative to the null hypothesis. In designing comparative clinical trials, α =0.05 is often used and power of at least 80%-85% is planned, variability is estimated from the previous studies, literature, historical known data or any prior experience and the alternative value of the hypothesis is determined by that which is clinically important. Many references and sources are available that show methods for computing sample size in different scenarios and underlying assumptions. There are many ready software available for sample size calculation available in the industry.

2. MULTIPLE TESTING

Considering the same example highlighted earlier in this paper for HDL cholesterol level increase, suppose that two such studies are conducted, one in each of the two independent centers. The significance level, α, is the probability of an erroneously significant finding, i.e. the probability of a significant result in Center 1 or Center 2 when H_0 is true. Using the law of probability states: For any event A,

Pr (A) =1-Pr (not A), you have

α = 1- Pr (a non-significant result in Center 1 and Center 2, when H_0 is true) = $1-\alpha_i$ (for i=1, 2)

Applying a law of probability which states that for any two independent events A and B.

Pr (A and B) =Pr (A). Pr (B), you obtain $\alpha = 1- (1-\alpha_1) (1-\alpha_2)$.

If $\alpha_1 = \alpha_2 = 0.05$, you have $\alpha = 1- (1-0.05)^2 = 0.0975$

In general, if there are k centers or k independent tests, each conducted at a significance level of 0.05, the overall significance level, α, is $\alpha = 1- (1-0.05)^k$, which is seen to increase markedly even for small values of k, as shown below;

k	α
1	0.050
2	0.098
3	0.143
4	0.185
5	0.226
10	0.401
15	0.537
20	0.642

This illustrate a problem encountered with simultaneously conducting many hypothesis. Although the tests usually will not be independent but the overall significance level will differ from the significance level at which the individual tests are performed. Multiple hypothesis testing often arises in the different ways in the analysis of clinical trials data, and the researcher must be aware of the any effects on the overall conclusions resulting from these situations.

3. MULTIPLE RESPONSE VARIABLE

Multiple comparison of Drug Response

We encounter many different multiple testing situations in the clinical trials. We highlight the example of the multiple testing situation arise in the comparison of a single response variable among more than two randomized drug groups, with 3 groups,

for example low dose group (active drug), high dose group (active drug) and placebo group, we compare the response of each active drug group to that of placebo group (control group), and compare the response of the low dose group and the high dose group. Multiple comparison can be designed to answer some key research questions when you have multiple drug doses (e.g. 5 mg, 10 mg, 25 mg, 50 mg, 75 mg, 100 mg, 150 mg, 200 mg etc.)

- ✓ Which active drug are better than a control group?
- ✓ Dose response improves with increasing dose of a drug?
- ✓ Which of the several doses is the most effective?
- ✓ What is the smallest effective dose?
- ✓ Which drug are statistically inferior to the 'best'?
- ✓ Is there a reversal of dose response at a higher dose?

In some cases, a statistical test designed to detect very specific alternative hypotheses can be applied to answer such research questions. The *Joncheere-Terpstra* test for monotonic dose response and the *Cochran-Armitage* test for liner trend are the different methods. Often, contrasts (linear functions) of group means can be used to help answer specific research questions about the relationships of the response among different dose groups. Sets of contrast can be simultaneously tested by using multiple comparison methods to adjust the p-value in order to maintain control of the overall significance levels.

Most commonly, the multiple comparison of drug effects are (i) to perform all pair wise comparisons among the drug groups, and (ii) to test each active drug group versus single placebo (control) group.

With K (Ke"3) groups, there are K. (K-1)/2 possible pair wise comparisons, however, then comparing each dose group with placebo, there are only K-1 comparison, a substantial reduction from the case of all pairwise comparison as shown in the table below:

Number of comparison for K=3 to 8

Number of Drug Groups	Number of Pairwise Comparisons	Number of Comparison with Placebo (Control) group
K	K(K-1)/2	K-1
3	3	2
4	6	3
5	10	4
6	15	5
7	21	6
8	28	7

In the study with 5 different dose group, there would be 10 possible pair wise comparisons. IF each of these is conducted at significance level of 0.05, the overall significance level is affected so the likelihood of obtaining at least one erroneous findings increases, this problem is easily overcome by using one or more of the many approaches to multiple comparison that will control the overall significance levels.

Many multiple testing methods are available, which are available in SAS software. The options available in SAS software helps to carry out the analysis using PROC ANOVA or PROC GLM where using appropriate options in the MEANS statement or LSMEANS statement with the ADJUST=option are used respectively in PROC GLM or PROC MIXED.

Multiple Response Variables

Another example in which multiple testing arises is when conducting individual test on many response variable. For example, testing for significant pre to post study changes in the laboratory assessments by conducting the individual Z or t-tests on a large number of laboratory parameters might result in chance significance. With 30 independent t-tests each at significance level 0.05, you would expect one test result to be significant due to the chance variation where there is no real deviation from the null hypothesis. If 30 or 50 or 100 tests are conducted on the laboratory assessment data, although not independent, we might expect a number of these to be falsely significant.

Multiple testing situations also arise when a clinical trial has more than one

primary end point associated with establishing the drug efficacy. The overall significance level for efficacy depends on whether at least one, some or all of the endpoints must individually attain a certain level of significance. Priority must be given to combinations of the primary response variables must show significance before drug efficacy can be declared, some combinations might require use of multivariate statistical methods or adjustments of the individual significance levels used to test each variable, some of many p-value adjustment methods are available to address the multiplicity problem.

We have very conservation, a simple Bonferroni adjustments is often used in these situations. For example, if just one of k co-primary response variable is significant, the Bonferroni method is used to test each of the k response variable at a significance level of α/k to maintain an overall significance level of α. A less conservative method can be used by taking into account the correlation among the response variables. Pocock, et al. (1987) have shown that with k normally distributed response variables and correlation of ρ between any pair, the tests can be conducted at a significance level that is slightly higher than the Bonferroni.

For two tailed test, adjusted significance levels needed to maintain an overall significance level of 0.05, when testing k Co-Primary Endpoints with Correlation ρ is as below:

K	Bonferroni	ρ=0.3	ρ=0.5	ρ=0.7	ρ=0.9
2	0.025	0.026	0.027	0.029	0.035
3	0.017	0.018	0.019	0.022	0.029
4	0.012	0.013	0.015	0.017	0.025

4. INTERIM ANALYSES

Interim analyses of ongoing clinical trial represents another situation involving multiple testing. Use of interim analyses has become widely accepted in the large or lengthy clinical trials. In some situations, it is looked upon the unethical to continue a clinical trial, when there is an overwhelming evidence of the efficacy of a new therapy, by continuing the study, patients might receive a placebo or other less effective drug that deprives them of the more effective drug. Assuming there are no safety

issues, it is generally preferable to make a new drug available to the patient at the earliest.

When decision is made to stop or to continue the trial or to change the trial in some fundamental way based on interim look at the data for the ongoing trial, the final significance levels will be altered. ***Group sequential methods*** are special statistical approaches that can be applied to handle such research problems, and in most cases, offers adjustments in order to maintain an overall significance level at a pre-determined value. The group sequential methods most commonly used in the clinical trials include those described by Pocock (1977), O'Brien and Fleming (1979), and Lan and DeMets (1983). The clinical trials planning at design stage is critical, where interim analysis is planned, since it becomes prime importance to protect the overall significance level α, since interim analysis can affect the overall significance level. The clinical trial protocol and statistical analysis plan should specifically detail out the following key points, these points are not explicit and are subject to change as per the clinical trial requirements.

- ✓ The number of interim analyses that are planned
- ✓ The purpose of interim analysis, how and when they will be conducted
- ✓ How analyses will be handled, which variables will be handled, how missing data will be handled etc.
- ✓ Any adjustments planned for the significance levels
- ✓ Blinded and Un-blinded teams involving scientific experts who will make required decisions for clinical trials.
- ✓ Data Monitoring Committee (DMC) to monitor the safety aspects of clinical trial

When interim analyses occurs without pre-planning, careful documentation must be kept to avoid compromising the study integrity. To maintain the overall significance level, such as $\alpha = 0.05$, the interim analyses must be conducted at significance levels little less than 0.05. Usually interim analysis are conducted at very small significance level such as 0.001 or less, so to conduct final analysis close to the 0.05 level. This is very conservative approach since it is extremely difficult to find a difference between drug groups at interim testing at such a reduced α-level. However, it might accomplish the purpose of identifying overwhelming drug differences early in the analysis while

permitting almost a full α-level test at the final analysis.

Pocock's Approach

Pocock (1977) proposed a group sequential method, the analysis at each stage of testing, including the final analysis, is conducted at the same reduced significance level α_p, in order to maintain an overall level of significance α (0.05), below is example of α_p, for 1 to 4 planned interim analyses.

Pocock's α_p, for α =0.05

Number of analysis	Number of Interims	α_p
2	1	0.029
3	2	0.022
4	3	0.018
5	4	0.016

O'Brien-Fleming Approach

The drawback of Pocock's method is that the final analysis is conducted at a level much smaller than the planned level of significance (i.e. 0.05). The O'Brien-Fleming approach (1979), is most widely used method in handling interim analysis in clinical trials. The method uses progressively increasing α levels at each interim analysis, so that final analysis is carried out between 0.04 and 0.05 level of significance (i.e. α_{OF}), which will be ideally close of 0.05 level of significance with 4 or less planned interim analyses.

Number of Analyses	Number of Interims	Planned Interim Analysis				Final Analysis
		1	2	3	4	
2	1	0.005				0.048
3	2	0.0005	0.014			0.045
4	3	0.00005	0.0042	0.019		0.043
5	4	0.00001	0.0013	0.008	0.023	0.041

For example, in two-stage design that uses the O'Brien Fleming approach with one scheduled interim analysis, hypothesis testing would be conducted at an interim

significance level of $\alpha_{OF=}0.05$. The clinical trial may be stopped with adequate statistical evidence of efficacy, if significance is found in favor of test drug. If 0.05 level of significance is not reached in the interim, the study continues to normal completion, at which time and hypothesis testing is conducted at significance level of $\alpha_{OF=}0.048$.

When clinical trial has one or more interim analyses planned, sample size can be calculated to achieve the required power. Since the final analysis of group sequential analysis is conducted at an alpha level smaller than the nominal alpha level of 0.05, usually sample size requirements are larger for the clinical trials involving interim analyses as compared to the clinical trials with no planned interim analyses. One of the key feature of the O'Brien Fleming approach is that sample size requirements are very close to those of the fixed sample size study, usually no more than 2% or 3% higher in order to achieve the same power.

Lan-DeMets α-Spending Function

The O'Brien Fleming approach was developed with an assumption that pre-specified interim analyses will be performed at approximately, equally spaced time interval during the clinical trial, based on patient recruitment. Simulations clinical trials have shown that this procedure is not greatly affected under the non-extreme deviations from this assumptions. In many cases, the number or timing of interim analyses cannot be pre-specified. Lengthy trials, for example, might simply request an interim analyses every 6 months but the patient data available for interim analysis may vary to greater extent since patient recruitment might not be uniform during the course of clinical trial.

Lan and DeMets (1983) introduced a method for handling multiplicity problem when number of interim analysis is not known at the planning stage. This method is based on "α-spending function" that allocates a portion of the overall significance level, α, for testing at each interim analysis, based on the amount of information available at that analysis ("information fraction").

The information fraction is usually based on the ratio of the number of patient available for the interim analysis to the total anticipated sample size if the trial were to go to completion. In some cases, the information fraction can be the fraction of elapsed time or, in the case of survival analysis, the number of deaths observed relative

to the number of death expected.

The rejection boundaries an interim testing levels can be obtained by using a computer program capable of evaluating multivariate normal probabilities, (while not available in SAS, many good software programs are available for computing these boundaries). The portion of α, available for all interim analyses up-to and including a specified information fraction. This cumulative α uses the O'Brien Fleming spending function and assumes a *two tailed symmetric test* with overall α = 0.05, very minimal alpha is allocated for interim analysis conducted by the mid-point of the clinical trial (information fraction=0.5).

Cumulative Lan-De-Mets α-Spending Function for the O'Brien-Fleming Spending Function, Tow Tailed Test at Overall α = 0.05.

Information Fraction	**Cumulative α**
0.1	0.00000
0.2	0.00000
0.25	0.00001
0.3	0.00009
0.333	0.00021
0.4	0.00079
0.5	0.00305
0.6	0.00762
0.667	0.01210
0.7	0.01477
0.75	0.01930
0.8	0.02442
0.9	0.03629
1.0	0.05000

Interim Analysis testing levels for the O'Brien-Fleming spending function under Lan-DeMets is shown in table below, these assure equally spaced interim analysis, during the clinical trial and are based on two tailed test with an overall significance level of 0.05.

Number of Analyses	Number of Interims	Planned Interim Analysis				Final Analysis
		1	2	3	4	
2	1	0.003				0.049
3	2	<0.001	0.012			0.046
4	3	<0.0001	0.003	0.018		0.044
5	4	<0.00001	<0.001	0.007	0.022	0.042

For example, a clinical trial involving three, equally spaced interim analysis would entail testing at 0.044 level at the final analysis, in order to maintain the two tailed α of 0.05 (assuming that the clinical trial foes to planned completion). As seen in table above, stopping the clinical trial at interim stage would require overwhelming evidence of efficacy, with significance at <0.0001 at that first stage, <0.003 at the second stage or <0.018 at third stage of testing.

5 SUMMARY

Many of the statistical terms used in this paper are used by clinical researchers, both statisticians and non-statisticians. The concept presented in this paper form a basis for general overview of hypothesis testing, significance levels, power, interim analysis etc., and the overall approach has to be planned as per the clinical trial requirements, considering the trial objectives and adhering to the regulatory submission guidelines.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] https://onlinelibrary.wiley.com/doi/abs/10.1002/9780471462422.eoct394

[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3856440/

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5052936/

[4] https://en.wikipedia.org/wiki/Interim_analysis

[5] https://www.fda.gov/regulatory-information/search-fda-guidance-documents/e9-statistical-principles-clinical-trials

[6] Common Statistical Methods for Clinical Research with SAS® Examples, Second Edition, Glen A. Walker.

REVIEW ARTICLE

A NOVEL CORONA VIRUS (COVID-19) PANDEMIC INSIGHTS

Pinakin R. Jani[(1)], Manish B. Thaker[(2)]

ABSTRACT

This paper highlights the background of COVID-19 spread, current situation, transmissibility of COVID-19, disease timelines-transmission without symptoms, global trends in confirmed cases, model confirmations, testing protocol, test details, recommended actions etc. These details will give more insights on the COVID-19 spread, present and future impact.

KEYWORDS:

COVID-19, WHO, Testing Protocol, GDP, NHFS, NTAGI, RT-PCR

1. INTRODUCTION

Coronaviruses (CoV) belong to the genus Coronavirus in the Coronaviridae. All CoVs are pleomorphic RNA viruses characteristically containing crown-shape peplomers with 80-160 nM in size and 27-32 kb positive polarity. Recombination rates of CoVs are very high because of constantly developing transcription errors and RNA Dependent RNA Polymerase (RdRP) jumps with its high mutation rate, corona viruses are zoonotic pathogens that are present in humans and various animals with a wide range of clinical features from asymptomatic course to requirement of hospitalization in the intensive care unit, causing infections in respiratory, gastrointestinal, hepatic and neurologic systems. They were not considered as highly pathogenic for humans until they have been seen with the severe acute respiratory syndrome (SARS) observed in China first time in 2002 and 2003. Before these outbreaks, there were the two most known types of CoV as CoV OC43 and CoV 229E that have mostly caused mild infections in people with an adequate immune system. Approximately ten years

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after SARS this time, another highly pathogenic CoV, Middle East Respiratory Syndrome Coronavirus (MERS-CoV) has emerged in the Middle East countries. In December 2019, 2019 novel Coronavirus (nCoV), which is another public health problem has emerged in the Huanan Seafood Market, where livestock animals are also traded, in Wuhan State of Hubei Province in China and has been the focus of global attention due to a pneumonia epidemic of unknown cause. At first, an unknown pneumonia case was detected on December 12, 2019, and possible influenza and other coronaviruses were ruled out by laboratory testing. Chinese authorities announced on January 7, 2020 that a new type of Coronavirus (novel Coronavirus, nCoV) was isolated. This virus was named as Novel Coronavirus WHO on January 12 and COVID-19 on 11 February 2020.

Background COVID-19 for India

India under COVID-19 pandemic has faced the largest national lock down in the world. India was quick to close its international borders and enforce an immediate lockdown, which WHO praised as **"tough and timely"**. The lockdown has also given the government time to prepare for a possible surge in cases when the pandemic is forecasted to peak in the coming weeks. Still, India's population of 1·3 billion across diverse states, health inequalities, widening economic and social disparities, and distinct cultural values present unique challenges.

In India's favour are its young population (65% aged <35 years) and, to date, a less severe pandemic than was feared. The lockdown is already having the desired effect of flattening the epidemic curve. Gradually has states began easing restrictions on the basis of district profiling of infection hotspots (a form of cluster containment). The immediate challenge is to keep infections at manageable levels and ensure the ability to test, trace contacts, isolate patients, implement COVID care plans, and disseminate timely information.

An excellent results were achieved initially based on strong decision, the central government will gradually loosen its control and give states more autonomy over their funding and decision making, which will enable the states wise control to handle the pandemic adhering to certain applicable national level guideline. India must also pay much greater attention to the health sector and recognize the importance of having strong public sector capacity, especially in primary care and at the district level. India's public health-care system is chronically underfunded (at just 1·28% of GDP), leaving primary care weak. This pandemic could be the much needed wake-up call to the

necessity of long-term changes to India's health care system. Health care systems will need to be enhanced with technology, more funding to become future ready to handle such unforeseen situation. The continuous efforts should be made in future years to make the health care system cost effective to benefit the humanity.

2. COVID-19 KEY POINTS

Data from china and model suggests that, by the time cases are recognized the transmission is ongoing and increasing with time. In India the initial infections was likely to arrive early February 2020. There are some key triggering questions with regards to the overall COVID-19 projections for India.

As per validated, simulated population of the Indian population based on National Family Health Survey (NFHS) and other national data. Previously used for National Technical Advisory Group of India (NTAGI) for vaccine introduction modeling, each individual in this simulated model represents an actual Indian in terms of age, income, location, health system access and other covariates found in NFHS data.

1) Why might India do better than other countries?
   - ✓ Relatively young population.
   - ✓ Seasonality that is expected for COVID-19 could delay infections into later in the year.

2) Why might India do worse?
   - ✓ Nutrition challenges in younger population relative to China and Italy with unknown impacts on children.
   - ✓ Greater opportunities for disease transmission and difficulty of social distancing.

Transmissibility of COVID-19 for India

The dynamics of transmission relationship is difficult to judge and explained, since there are many factors that influence the transmission. Social distancing, medical care, quarantine, geographical factors, and the average number of people the infected person will affect etc. Based on the contact rate the key analysis question is, how many people the person contacts and the probability the virus transmitted.

Reproduction Number (R_0) which is the average number of people an infected person will infect, the best estimate is that (R_0) is between 2 and 3, emerging evidence that increased temperature and humidity would reduce this to 1.8 in a month.

Disease Timeline: Transmission without symptoms for India

There are multiple disease parameters of interest, few of those are highlighted

below

- ✓ **Incubation time:** 6 days (SD 2 days)
- ✓ **Time to hospitalization:** 3.5 days (SD 1.8 days)
- ✓ **Days in Hospital:** 12 days (SD 3.4 days)
- ✓ **Contagious time non-hospital:** 9 days (SD 3 days)

The dynamics are slowed in India region, people who will show symptoms next week are already infected and incubating the virus. Some of these will transmit before they are symptomatic.

Model Assumptions

Contact and Transmission depends on type of contact and with whom contact is made

- ✓ Contact patterns highly variable by age (e.g. kids and elderly people have higher rates of contact).
- ✓ Household contact rates are higher than outside contacts.

Evidence from China indicates that higher temperature and humidity are likely to lower the transmission rates but it is unclear how this will translate to the India context.

Some Key Observations:

- ✓ A large percentage of cases are mild, but for older individuals the mortality rate is strikingly higher. In China mortality was much higher in the elderly population.
- ✓ Children are less likely to be infected and also less likely to be hospitalized than adults.
- ✓ Illness is less likely to be severe in children than in adults.
- ✓ Children have overall lower levels of severe or critical infection than adults.

3. TESTING PROTOCOL, TEST DETAILS & RECOMMENDATIONS

Diagnostic testing is at the center of the policy debate around COVID-19 interventions in India. As of June 1, 2020, India had conducted approximately 3.8 million tests since it began testing in February,1 but many experts have noted that testing capacity is still drastically insufficient for the needs of the population. Daily COVID-19 tests per 1,000 people are only 0.08 in India compared with 1.16 in the United States and 1.02 in Italy (as of May 30, 2020). India's COVID-19 test positivity rate is about 5 percent (as of June 1, 2020) within the World Health Organization's recommended rate of <10 percent. While this number might suggest that testing

capacity is currently sufficient for the size of the outbreak, analysis indicates that a nearly tenfold increase in testing is required to keep the positivity rates low. Delays in testing have hampered the COVID-19 response in Europe, the United States, and Brazil, inadequate testing capacity in India may prove to be an even greater challenge.

The Indian government's current approach to testing has three key aspects:

1. The Indian Council for Medical Research (ICMR) recommends real-time RT-PCR2 throat/nasal swab tests as the gold standard for COVID-19 diagnosis.
2. The Indian government recommends pooled sample screening by PCR in areas and for popula-tions with COVID-19 positivity rates of <5 percent to increase laboratory capacity for screening surveillance samples.
3. Authorities are simultaneously looking for a reliable rapid antibody test for epidemiological and surveillance purposes.

The RT-PCR throat/nasal swab test has been the key diagnostic test used in India. The rapid antibody tests were withdrawn by ICMR within a few weeks of use over reliability concerns. However, ICMR has recently encouraged states to conduct serosurveys using an IgG ELISA3 test.

While the RT-PCR test diagnoses current infection by detecting the presence of live virus, the antibody test provides infor-mation about the history of infection by detecting antibodies specific to COVID-19. In the early stages of an epidemic, or after a period of suppression, RT-PCR is useful to identify infected persons, trace their contacts, and isolate them to limit the spread of infection. The rapid antibody tests are better suited to epidemiological studies and surveillance assessments of the proportion of a population with immunity to COVID-19. Such tests can help guide social isolation policies and potentially get people who are immune back to work. The differences between the two tests are summarized in this section.

There are currently over 100,000 tests being carried out in India every day (e.g., 100,180 tests were conducted on June 1, 2020). The government aims to double this number to 200,000 tests but as the experiences of Europe and the United States show, testing would actually have to expand tenfold or more over the next few weeks to accurately estimate the true number of cases, to achieve a meaningful epidemiologic understanding of the prevalence, and to guide measures as the economy reopens. Such a large-scale increase of COVID-19 testing in India would put the testing supply chain's scaling-up ability to the test. There have already been a number of recent reports highlighting shortages in es-sential supplies for COVID-19 testing, long turnaround times for test results, and delays in timely no-tification and isolation of

positive cases. Testing has value only when there is proper interpretation of test results and mandated follow-up actions related to containment. In this note, we explain how the SARS-CoV-2 testing supply chain in India is organized, describe the underlying structural bottlenecks, and provide some recommendations for how the country can expand timely and effective testing for the battle against COVID-19.

Comparison of RT-PCR and rapid antibody tests

	RT-PCR Test	Rapid Antibody Test
What is it?	Reverse-Transcription Polymerase Chain Reaction (RT-PCR) test directly tests for the presence of the virus RNA (ribonucleic acid). It involves extracting RNA from the nose or throat swab samples and converting them into DNA.	The antibody test looks for both COVID -19 IgM and IgG antibodies in the blood. IgM antibodies are detected within one week of infection, and IgG antibodies develop in about one to two weeks after infection. The antibody test is a supplementary tool to assess disease prevalence in a specified area.
Is it available in India?	There are three types of RT-PCR tests being used in India for COVID -19 testing: (1) ICMR-validated RT-PCR; (2) Truenat from MolBio Diagnostics; and (3) Cartridge-based GeneXpert from Cepheid.	Rapid antibody tests were introduced in several Indian states for surveillance purposes but were later withdrawn over reliability concerns. ICMR evaluated the kits of Guangzhou Wondfo Biotech and Zhuhai Livzon Diagnostics in field conditions and withdrew them upon finding wide variations in their results. Recently, the indigenous IgG ELISA test "COVID KAVACH ELISA" has been approved.
Use and advantages	• (i) Detects virus at an early stage and is advocated by ICMR as the best strategy for the identification of individuals with COVID-19 infections, the tracing of their contacts, and isolation. • (ii) Sensitive and reliable test capable of producing results in three to four hours, although it usually takes longer if samples must be transported from collection centers to specialized external laboratories. • (iii) Pooled samples for screening by RT-PCR increases the number of tests conducted by laboratories. All individual samples in a negative pool are regarded as negative. Deconvoluted testing is recommended if any part of the pool is positive.	• Antibody tests detect a patient's immune antibody response to the virus rather than detecting the virus itself. • The IgG antibody tests are largely useful for epidemiological studies and surveillance purposes. IgM antibodies can be used for diagnostic purposes because they are detected within one week of infection. • This test may guide social isolation policies and potentially get people who are immune back to work. However, (as of April 24, 2020), no study had yet evaluated whether the presence of antibodies to SARS-CoV-2 confers immunity to subsequent infection by the virus in humans. Antibody tests based on detecting neutralizing antibodies are better in assessing future protection from reinfection compared with antibodies that are not neutralizing. • The antibody test produces results quickly, often within 15 minutes.
Disadvantages	• The RT-PCR test is less effective toward the end of a period of infection. • It is comparatively slower to produce a result.	• The IgG antibody test is less effective during the earlier stages of infection and may therefore produce a false negative. • The test can determine if a person was at some point infected with COVID -19 but cannot confirm active infection. IgM antibodies are suggestive of acute infection. • The technology is new and the test's reliability is still being evaluated.

Health is a state subject in India. While the central government designs the testing strategy, the states implement it. This has resulted in variations among states in the scale of testing. Overall preparedness and response to COVID-19 have also differed from state to state.

4. TEST SITES AND LABORATORIES: EVOLVING CAPACITIES AND STANDARD OPERATING PROCEDURES

ICMR is the lead agency for the COVID-19 testing strategy in India. It began the COVID-19 testing op-eration by leveraging the approximately 106 Viral Research and Diagnostic Laboratories (VRDL) it had helped establish over the last few years at the regional, state, and medical-college level. Initially, the VRDLs were the only sites designated to collect samples for COVID-19, which they would then send to the National Institute of Virology (NIV) in Pune for RT-PCR testing. A contracted courier agency trans-ported the specimens from the VRDLs to the central NIV lab. Over time, government operating proce-dures changed to allow the VRDLs to carry out the tests themselves. Subsequently, testing was initiated in partnership with laboratories in the Department of Science and Technology, Department of Bio-technology, the Indian Council of Agricultural Research, the Council of Scientific and Industrial Re-search, the Defense Research and Development Organization, the Ministry of Human Resource Devel-opment, medical colleges, and private laboratories. As of May 31, there were 472 government-owned labs and 204 private laboratories authorized for lab testing.

There are three types of molecular-based tests currently being used: ICMR-validated RT-PCR, MolBio Diagnostics' Truenat, and Cepheid's cartridge-based GeneXpert. A breakdown (as of May 31, 2020) of these tests, which are being used nationwide in the 676 public and private laboratories testing for COVID-19, and which are reporting to ICMR are:

Real-time RT-PCR for COVID-19: 481 (government: 313 + private: 168)
Truenat test for COVID-19: 140 (government: 131 + private: 9)
CBNAAT4 for COVID-19: 55 (government: 28 + private: 27)

When a VRDL first begins conducting testing, it must send its first 10 negative samples to NIV for cross-validation. It must also send a proportion of the all positive

test samples to NIV (private labs must send all positive samples). Blood and serum samples must be collected from all positive patients and sent to NIV. This creates additional sample flows in the testing supply chain, which are presently being met but that could become a challenge if capacity (in terms of number of labs and/or of number of tests conducted per lab) increases tenfold. Further, given that a cold chain must be maintained throughout sample transit, such significant additional sample flows would increase the risk of cold-chain breaches.

The Indian government has been continuously attempting to adapt and update standard operating procedures to improve its testing abilities. In addition to making testing labs more available, it has re-vised its initial recommendation that Truenat only be used as a screening test requiring confirmation by a RT-PCR test. ICMR now declares the Truenat system to be a comprehensive assay for screening and confirmation of COVID-19 cases. While RT-PCR is limited to well-equipped hospitals, Truenat can be deployed at district hospitals across the country.

5. LEVERAGING THE COUNTRY'S PRIVATE SECTOR: PROGRESS IN MADE-IN-INDIA SUPPLIES, BUT MORE IS NEEDED

The Indian government has partnered with domestic industry to build self-reliance in its testing ca-pacity. The indigenous production of swabs for testing COVID-19 has begun, with more than 200,000 swabs now being manufactured per day. Fourteen of the 28 RT-PCR testing kits approved by ICMR validation centers are locally produced. An indigenous manufacturer has also developed a viral ex-traction kit. Truenat, a fully indigenous diagnostic platform developed for tuberculosis, has now been validated by ICMR for COVID-19 testing. And a completely indigenous IgG ELISA test for antibody detection of SARS-CoV-2 has been developed and validated by NIV. There is now a greater openness toward various government research and development labs to collaborate with private industry in production.

As mentioned earlier, to augment the Indian government's testing efforts, 204 private labs are also testing. This number is low because COVID-19 testing in private laboratories is limited to those with an accreditation certificate from the National Accreditation Board for Testing and Calibration Laborato-ries (NABL), and the scope of accreditation includes real-time PCR for RNA. There are only 223 private labs

out of more than 1,100 NABL labs in India that meet these criteria (government laboratories are exempt from such stringent rules), limiting the ability to substantially harness the country's private sector testing capabilities. Adding to the regulatory obstacles, private labs have stressed that the pro-curement of specialized and expensive equipment, trained manpower, and space are major barriers to initiating COVID-19 testing. Substantial capital investment is needed for every new COVID-19 test-ing facility. Private labs (but not government labs) are also required to transport all positive samples to NIV leading to costly and time-consuming sample flows. Finally, private labs may be further dis-couraged by the stigma associated with COVID testing, resulting in a substantial decrease in routine lab work.

6. PROCUREMENT AND DISTRIBUTION

The primers, probes, master mix, positive control, and RNase P5 that government labs require are procured by the central government of India (until recently by ICMR and now by HITES6). At the very start of testing, supplies were being shipped to the testing labs from the stocking depots and storage locations at NIV Pune or ICMR Delhi. Originally, orders placed to suppliers were received at these two sites, but over the past few weeks another 14 regional depots have been introduced for supply distri-bution to expedite the process. Appendix 2 lists the regional depots for the storage and transportation of COVID kits. These 16 regional depots (including two central depots) have been assigned government laboratories for distribution of COVID-testing-related supplies. The intent was to remove bottlenecks from the system by decentralizing stockholding closer to the testing labs. The labs can now order their supplies directly from these depots, and the depots must forecast and communicate their needs for the coming weeks to ICMR/NIV, which then communicates with suppliers for direct delivery to the depot.

In addition to supplies provided by ICMR, state governments are responsible for suppling viral trans-port media for sample collection, RNA extraction kits, and other needed consumables. While ICMR is responsible for supplies related to the step of conducting RT-PCR, the states procure supplies re-lated to the sample collection and RNA steps. Variations among states in their adopted procurement mechanisms are likely. The regional depots may be processing both lab-level and state-level stock

requests and deciding quantity and items to be dispatched to each linked lab and state. Managing the distribution of supplies related to COVID-19 testing but procured through different mechanisms adds complexity for these depots. Appendix 3 provides details on the assignment of procurement respon-sibilities between ICMR and state governments.

Private laboratories are required to procure their own supplies for carrying out COVID-19 tests. The government had previously capped the price of COVID-19 tests by private labs to a maximum of INR 4,500. Recently, ICMR recommended that state governments and union territory administrations negotiate with the private sector to arrive at lower prices because there has been a decrease in test-ing-related costs due to increased market competition and availability of indigenous testing materials and kits, which has driven down testing supply costs.

In addition to PCR testing, ICMR had also procured antibody-based rapid diagnostic tests (such as ELISAs), which pick up past (as opposed to active) infection. These tests were withdrawn within a few weeks of their introduction but have recently been permitted again.

7 SUMMARY

The background and the insights gives clear indication for India as well as global countries that there is more robust actions required to deal with existing challenge. The dynamics are quite volatile and every country has to gradually get ready to handle the impending challenges post COVID-19 to strengthen the overall health care system.

8. ACKNOWLEDGEMENT

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9. REFERENCES

[1] Abha Mehndiratta, Kalipso Chalkidou, Krishna Reddy, Prashant Yadav and Sidharth Rupani, India's COVID-19 Testing Capacity Must Grow by a Factor of 10, Here's How That Can Happen*, by, Center of Global Development, CDT Note JUN2020.*

[2] Aditi Sriram, Arindam, Geetanjali Kapoor, Isabel Frost, Nandi, Katie Tseng, Ramanan Laxminarayan, Covid-19 India: State-level Estimates of Hospitalization Needs, The center of Disease Dynamics, Economics and Policy (CDDEP), Princeton University.

BIOGRAPHY

DEBABRATA BASU*

H. D. Budhbhatti**

Debabrata Basu
(5 July 1924 – 24 March 2001)

Debabrata Basu was born in Dacca, Bengal, unpartitioned India, now Dhaka, Bangladesh. His father, N. M. Basu, was a mathematician specialising in number theory. Young Basu studied mathematics at Dacca University. He took a course in statistics as part of the under-graduate honours programme in Mathematics but his ambition was to become a pure mathematician. After getting his master's degree from Dacca University, Basu taught there from 1947 to 1948.

Following the partition of India in 1947, Basu made several trips to India. In 1948, he moved to Calcutta, where he worked for some time as an actuary in an insurance company. In 1950, he joined the **Indian Statistical Institute** as a research scholar under **C.R. Rao.**

In 1950, the Indian Statistical Institute was visited by Abraham Wald, who was giving a lecture tour sponsored by the **International Statistical Institute.** Wald greatly impressed Basu. Wald had developed a decision-theoretic foundations for statistics in which **Bayesian statistics** was a central part, because of **Wald's theorem** characterising admissible decision rulesas Bayesian decision rules (or limits of Bayesian decision rules). Wald also showed the power of using measure-theoreticprobability theory in statistics.

In 1953, after submitting his thesis to the University of Calcutta, Basu went as a Fulbright scholar to the **University of California, Berkeley.** There Basu had intensive discussions with **Jerzy Neyman** and "his brilliant younger colleagues" like Erich Leo Lehmann. Basu's

* Adapted from wikipedia (the free encyclopedia) and other related resources. (We express our sincere thanks and gratitude for this assistance)

** Ex. CSO, Head , Statistics Dept. , GSRTC, Ahmedabad

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(rcd May 2020 / rvd June 2020)

theorem comes from this time. Basu thus had a good understanding of the decision - theoretic approach to statistics of Neyman, Pearson and Wald. **In fact, Basu is described as having returned from Berkeley to India as a "complete Neyman Pearsonian" by J. K. Ghosh.**

Basu met Ronald Fisher in the winter of 1954–1955; he wrote in 1988, "With his reference set argument, Sir Ronald was trying to find a via media between the two poles of Statistics – Berkeley and Bayes. My efforts to understand this Fisher compromise led me to the likelihood principle". In their festschrift for Basu, the editors Malay Ghosh and Patak write that [Basu's] critical examination of both the Neyman–Pearsonian and the Fisherian modes of inference eventually forced him to a Bayesian point of view, via the likelihood route. The final conversion to Bayesianism came in January 1968, when Basu was invited to speak at a Bayesian Session in the Statistics Section of the Indian Science Congress. He confesses that, while preparing for these lectures, he became convinced that Bayesian inference did indeed provide one with a logical resolution of the underlying inconsistencies of both the Neyman–Pearson and the Fisherian theories. Since then, Dr. Basu became an ardent Bayesian and, in many of his foundation papers, pointed out the deficiencies of both the Neyman–Pearsonian and the Fisherian methods.

After 1968, Basu began writing polemical essays, which provided paradoxes to frequentist statistics, and which produced great discussion in statistical journals and at statistical meetings. Particularly stimulating papers were Basu's papers on the foundations of survey sampling. There is an extensive literature discussing Basu's problem of estimating the weight of the elephants at a circus with an enormous bull elephant named Jumbo, which Basu used to illustrate his objections to the Horvitz–Thompson estimator and to Fisher's randomisation test.

Basu taught at the **Indian Statistical Institute and various universities around the world**. He moved to the United States and taught statistics at Florida State University from 1975 to 1990 when he was made an emeritus professor; he has supervised six PhD students. In 1979 he was elected as **a Fellow of the American Statistical Association.**

Publications

* Basu's main articles are reprinted with his comments in Basu, D. (1988). J.K. Ghosh (ed.). Statistical information and likelihood : A collection of critical essays by Dr. D. Basu.
* Lecture Notes in Statistics. **45**. Springer.ISBN 0-387-96751-6. MR 0953081.
* Basu, D. (September 1980). "Randomization Analysis of Experimental Data: The Fisher Randomization Test". Journal of the American Statistical Association.

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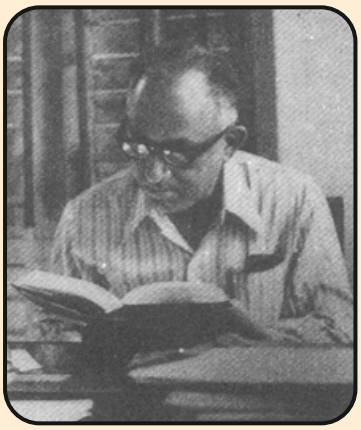

Debbrata Basu was an Indian statistician who made **fundamental contributions to the foundations of Statistics**. He was born on 5th July 1924 in **Decaa, Bengal**, Unpartitioned India, now **Dhaka, Bangaladesh**. His father was a mathematician specialised in number theory. Basu studied Mathematics at Dacca University. His ambition was to become a pure mathematician. He received master's degree from Dacca University. He taught there from 1947 to 1948. He got Ph.D. degree in 1953.

Basu invented simple examples that displayed some difficulties of likelihood based statistics and frequentist statistics. Basu's paradoxes were especially important in the development of survey sampling.

In statistical theory, Basu's theorems established the independence of a complete sufficient statistics and an ancillary statistic. Basu came in close contact with renowned persons like **C. R. Rao, J. Neyman, Ronald Fihser, J. K. Ghosh** etc.

Basu was associated with **ISI, Calcutta and Florida state university in USA**. His life ended on 24th March, 2001.

***(Brief Biographical sketch is given inside the journal)**

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