Productivity Impact Analysis from Artificial Intelligence Monitored GIS and IoT Data of Sugar Industries

Amol Chavan
Vidya Pratishthan's Institute of Information Technology (VIIT), Baramati

Majharoddin Kazi
Dept. of Comp. Appl.
JSPM University
Pune

Santosh Parakh
Dept. of MCA,
Siddhant Institute of Computer Application, Sudumbre,
Pune

ABSTRACT
The sugar industry stands as one of India's most prominent and rapidly expanding manufacturing sectors, with Maharashtra leading in production growth. As of December 2022, India's sugar output reached 82.1 lakh tonnes - an increase of 5.1% over the previous year - highlighting the sector's robust performance even before accounting for ethanol-related diversions. Beyond its economic contributions, the establishment of sugar factories in rural areas catalyzes socio-economic development by fostering ancillary activities such as dairies, poultries, irrigation schemes, and community services including healthcare, education, and cultural initiatives. This diversification drives rural industrialization and employment generation.

In parallel, the integration of Information Technology (IT) has revolutionized agricultural practices within the sugar industry. Technologies such as RFID, smart sensors, IP cameras, and temperature monitoring systems are increasingly deployed to enhance farm management. The emergence of the Internet of Things (IoT) offers a unified framework to connect these decentralized systems, enabling smarter, data-driven agriculture. Precision agriculture (PA), supported by GPS, GIS, and remote sensing (RS), further empowers stakeholders with spatial and non-spatial data for optimized resource use and yield forecasting.

Artificial Intelligence (AI) adds another transformative layer, enabling real-time tracking, automated harvesting, and advanced analytics through drones and agricultural robots. These innovations facilitate weed detection, crop quality assessment, and yield estimation, positioning AI as a cornerstone of future-ready sugarcane farming. Collectively, these technological advancements promise a more productive, sustainable, and inclusive sugar industry - benefiting farmers, workers, and rural communities alike.

General Terms
Sugar Industry, Pattern Recognition, Internet of Things, Deep Learning

Keywords
AI, Sugar production, GIS, Sugarcane, Productivity Enhancement, Data Analysis

1. INTRODUCTION
Sugar Industry is one of the most notable and large-scale sugar manufacturing sectors in the country. The pace of growth of sugar manufacturing has been massive over the past few years. The latest statistics of sugar production in Maharashtra indicate that this state this doing better than the other states in the country [1].

The sugar production of India till December 2022 at 82.1 lakh tonnes is higher by 5.1% over previous year. The sugar till December is 82.1 lakh tonnes, against 77.9 lakh tonnes produced during the corresponding period of previous year, up by 4 lakh tonnes. The sugar production figures are before diversion of sugarcane juice for ethanol production. When a sugar factory is established in a rural setting it becomes possible for the organization to help generate various ancillary activities for the benefit of local farmers and other members of rural society. Sugar factory provides the basis for organization other economic activities such as modern poultries, dairies, irrigation schemes, activities which contribute largely to the betterment of the economic conditions not only of the farmers but also landless labors and other people in the area as well of Vendors, Customers and Employees etc. The factory also establishes school, heath centers for medical facilities with modern hospitals and dispensaries and organizes various cultural and sports activities. A considerable amount is set apart by many co-operative and private factories to make the life of the local inhabitants more purposeful and meaningful. Thus, diversification of production activities leads to a process of rural industrialization which also is employment generating [2].

During last decade, progress in Information Technology has affected all spheres of our life. IT is assuming ever increasing importance in agricultural development of the country. Likewise, IT has major role to play in sugar industry. There is no doubt about potential of IT, as it has a variety of tools / technologies available for sugar and its allied industries which can not only change the economic and social life of sugar industry but also, its stakeholders viz. owners, millers, vendors, suppliers, customers, farmers, employees, local communities etc. progressive change resulting in better life for the community as a whole [3].

In the current scenario of technological development, it is possible to control and manage the agriculture farms using smart devices like RFID (Radio Frequency Identifier), smart sensing devices, IP (Internet Protocol) cameras, temperature monitoring systems, etc. these devices are decentralized and work independently without any integration between them. To override this difficulty an internet-based technology called the Internet of Things (IoT) has emerged in recent past years. IoT is the third advancement of science and technology industry in the world after the computer, internet and mobile communication networks [4].

Yield maps provide essential information to guide precision agriculture (PA) practices. Yet, on-board yield monitoring for sugarcane can be challenging. At the same time, orbital images have been widely used for indirect crop yield estimation for many crops like wheat, corn, and rice, but not for sugarcane. Agricultural management requires access to accurate and current information (spatial and non-spatial) that helps in planning and executing activities that lead to improvement in

the productivity of the land and input use efficiency. In agriculture, global positioning system (GPS) and geographic information system (GIS) technologies have been adopted for better management of land and other resources for sustainable crop production. Acquiring spatial data in GIS platform and remote sensing (RS) plays a major role in information management systems. RS is an accurate, efficient, economical and reliable technique to prepare a comprehensive inventory of the natural resources of an area [5].

Together with precision agriculture (PA) and other emerging technologies like IoT, artificial intelligence (AI) can play a key role in modernizing agricultural practices and achieving the goal of improving the productivity of alternative arable cropping systems. In offering progressive change with advanced approaches, AI's future in agriculture and in Sugarcane is well ahead [6].

In the agricultural sector, Artificial Intelligence (AI) is an emerging technology. AI-based equipment and machinery took the agricultural system today to a new level. This technology has increased crop production and enhanced tracking, harvesting, processing, and marketing in real time. In Sugar Industry, the new developments for automated systems using agricultural robots and drones have made a considerable contribution. Different hi-tech computer-based systems are designed to recognise various important parameters such as weed detection, crop quality and yield detection and many other techniques [7].

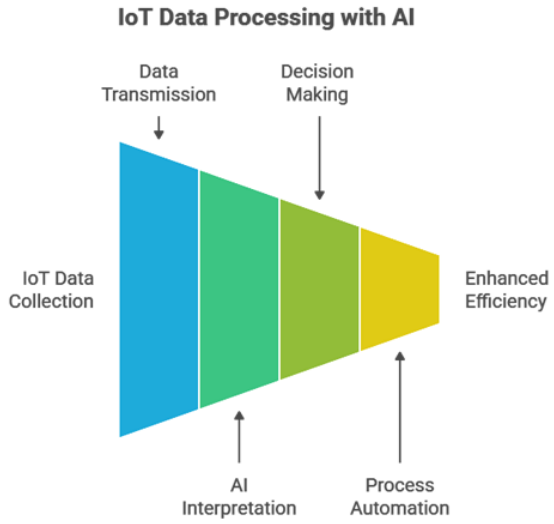

Fig. 1. A simplified workflow of IoT system and the role of artificial intelligence

The aim of this proposal is to review agricultural intelligence applications from GIS, GPS and IoT data collected in Sugar Factories and to reduce the use of colossal amounts of chemicals with the aid of these technologies, resulting in reduced spending, improved soil fertility and increased productivity. With AI tools and machine learning, Sugarcane farmers can improve yields, protect their crops. By implementing AI-Sugar framework using GIS, GPS and IoT will highly reduce the unwanted usage of resources in the not only Sugar Factory but also farmlands and improve the productivity level. IoT and GIS will give real-time data about the land, machinery, and another resource for all the three stakeholders (farmer, mills, and government). Based on this live data, immediate action can be taken by the decision-makers to control and monitor the growth environment of sugar cane, achieve a high and stable yield of sugar cane, improve the productivity of land, monitor the pesticide level in the crop, water level, soil moisture and control the cultivation wastages, etc [8].

Sugar Industry is a very scientific business with a lot of analysis, thinking and agronomy. If the research could get the right data in front of the right people at the right time, the research could improve Sugar production by small percentages. The trick has been to look at areas that provide the best returns on our technology investment and can boost the productivity [9].

2. LITERATAURE REVIEW

With the advent of technology, there has been observed a dramatic transformation in many of the industries across the globe [10]. Surprisingly, agriculture, though being the least digitized, has seen momentum for the development and commercialization of agricultural technologies. Artificial Intelligence (AI) has begun to play a major role in daily lives, extending our perceptions and ability to modify the environment around us [11].

A method for harvest planning based on the coupling of crop assignment with vehicle routing is presented. With these emerging technologies the workforce which were restricted to only minimal industrial sectors are now contributing to numerous sectors. AI is based on the vast domains like Biology, Linguistics, Computer Science, Mathematics, Psychology and engineering [12].

Sensory devices and wireless technologies play a vital role for monitoring the real-time temperature data of any farmland. Stakeholders (farmer, mills, and government) can facilitate with a live monitoring system and respond instantly if any variations required in the production process [13].

Researchers have proposed a systematic method for seasonal climate forecasting system to progress the risk management and decision-making capacity across all sugarcane industry sectors. The approach explores the vital role of R&D approach with stakeholders and explains the importance of value chain for sugar production [14].

A control and information network integrated IoT technology for agricultural production. They adapted remote monitoring and tracking system for the proposed method. By adopting information management system, the real-time data is collected for further analysis [15].

Vijayanagar Sugar Pvt. Ltd. Karnataka is engaged in manufacturing sugar and its byproducts like molasses, bagasse & ethanol. They need remote monitoring & logging of data of their key parameters like pressure & flow of steam, level & flow of juice and furnace temperature. All these parameters were emanating from the already installed field instruments at various locations. They were keen in improving their process performance and efficiency through optimum utilization of thermal & electrical energy, minimizing process downtime and inventory management for preventing loss of raw materials and products. So, they installed and commissioned IIoT based remote monitoring system and fine-tuned it to suit their requirement. All the sensors are connected to the gateway panel, to log real time data on cloud through GPRS wireless network so that, all data is available on display in the centralized control room. Moreover, this data is also made available on personal computers & smart phones with multiple authorized log-in facility to enable accessibility on 24 x 7 basis at any place. Collected data is presented in various analytical forms such as historical trends, bar graphs or CSV formats to

afford comparative study to help take quick & intelligent decisions and initiate appropriate actions. Hence installed system is already saving huge man-hours and resources on activities like data collection, analysis & preparation of report [16].

The opportunities from advance IT tools for effective management of data in sugar mill zones. Further, IT tools already developed for sugar industries has been escribed. An effective implementation of IT tools and techniques like Artificial Intelligence, GIS applications, MTS applications, Multimedia, Internet technologies etc. will aid in entire business cycle of sugar industry for more profit [17].

3. RESEARCH GAP

After lot of literature reviews and observations it is found that IT system supports various operations from cane cultivation, registration to factories and harvesting to its payments to farmers accounts. It provides benefits such as increase in yield to farmers, timely crushing gives good sugar quality all these leads to benefits of supply of input to farmer, farmer's loyalty, redeployment of human resources, efficient bank transaction management, industry automation etc [18].

Large numbers of industries fail in proper IT implementation. Information Technology implementation affects all aspects of organization starting from strategic, structural, and cultural to day-to-day operation and workflow. There are different strategies for successful implementation of IT such as Multi Criteria Decision Making (MCDM), Analytical Hierarchy Process (AHP) and new paradigm for improving goal setting [19].

There are pieces of software or small ERP systems are developed for sugar industry. They are using obsolete technology and application software which are not fulfilling their information needs. There are various issues related to manpower training and other factors affecting on IT implementation viz political, economic, social, psychological, environmental and legal. Previously done research is focusing on effect of implemented software or ERP packages in sugar industry only from the management perspective but there is much need to study impact and effect on Productivity of this industry as well. Therefore, there is a need of further research and adoption of an integrated model for maintaining IT resources using AI. Success factors of IT implementation are based on organization culture, project structure, top management support, training issues, change management and technological migration [20]. Researchers faced with unique difficulties that are not familiar to other sectors of the economy. But The problem here is that there is no clearly stated procedure to be taken such as the number of sensors to be deployed and which kinds remote sensing technology widely used for Agronomist.

Researchers in their research focusing on the Internet of things technology, has designed and implemented a set of sugarcane growth monitoring system according to the growth characteristics of sugarcane crops. This research paper shows that IoT for Sugarcane growth monitoring and cost reduction does not reflect the productivity of sugarcane in terms of cane growth [21].

This research will demonstrate the Productivity Impact Analysis from Artificial Intelligence monitored GIS and IoT data of Sugar Industries. IoT and GIS will be potentially impacting are economical (e.g. increased productivity, lower production cost, and higher quality), environmental (e.g. less resource consumption, lower emission and carbon footprint) as well as social (e.g. improved public health, consumer demand driven, quality of life improvement). The pace of innovations in the field of IoT, GIS, and AI are astounding and tasks that seemed impossible a few years ago have now been implemented with great success. Embracing the technology innovations and putting them to advantage are important for success of modern agriculture and Sugar industry [22].

To achieve the aim of the study, the work will investigate and answers the following research questions:

- What is the status of the Sugar Industry?
- What types of IoT Technologies Improve Sugar Production?
- How to determine the suitability of the soil moisture, crop conditions and weather conditions for Sugarcane using IoT and GIS?
- Has AI based GIS technology enhanced crop production and improved real-time monitoring, harvesting, processing and marketing?
- How to improve the Production of Sugar Industry by using AI, GIS, and IoT Technology?

Existing research provides limited information about new Information Technology Tools and their impact on Sugar Industry. Lots of new tools and techniques are invented now a days for various agro based industries and their operations ease. Some pilot experiments in IoT & GIS with reference to Sugar domain found to be very effective in problem optimization. These new techniques are yet to study in Sugar Industry as well as stakeholder's angle for their effectiveness from socially, economically as well as legal application of Artificial Intelligence [23].

To summarize review of the related works, I found a major gap in the current literature and the review started by exploring the concept of IoT, GIS, AI etc. with its technology and architecture and discussed about Sugar Industry. This shows that there is a gap in the improvement of this industry's production sector. In the review one of the challenges identified in the sugarcane sector in the country is lack of automated technologies to manage and control production sugarcane plants and adoption of recent technologies in this sector. IoT, AI, GIS etc. advanced technologies for Sugarcane growth monitoring and cost reduction does not reflect the productivity of Sugar Industry in terms of cane growth and cane crushing as well as optimal use of factory resources (Man, Machines and Money). Seeing this as a gap and to fill by increase sugarcane production by using IoT, GIS etc. technology and to identify the factors addresses like environmental factors temperature, humidity and soil moisture level plays a major role for the growth of cane plant with improve sugarcane production can be shown. In addition, the research has been able to solve this problem and the way to increase sugarcane productivity and prevent high usages of factory resources, there was a need to design an AI based technologies to manage and improve productivity [24].

4. IDENTIFICATION OF PROBLEM

There is little effort to increase sugar productivity in our country with the help of technology. The main reason for the decline in sugar production is the lack of proper resources utilization at factory level as well as field level. To solve this problem, it is possible to make an informed decision and technically solve the problem and improve production using advanced IT systems like AI, IoT, GIS technologies [4].

To provide efficient information technology system using integration of Artificial Intelligences with IoT, GIS/GPS

technologies will give useful and quick information related to various areas and segments related to Sugar Industry. Information related to farms, production, supply, logistics, costing, accounting, weather forecasting, human resources, MIS etc [25].

4.1 Scope of the Proposed Work

The scope of this research is to identify Productivity Impact Analysis from Artificial Intelligence monitored GIS and IoT data of Sugar Industries and their stakeholders. This proposed research will study the data generated from IoT and GIS cloud systems from 20 sugar factories across Maharashtra but not limited to this.

5. RELEVENCE OF THE WORK

An AI based Expert System is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Expert in crop production and protection are the modem extension tools for decision support at farmer level. It can suggest suitable variety, method of field preparation and sowing, irrigation, fertilizer application, etc. Disorder diagnosis and treatment are one of oldest application of expert system [26].

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Major application of GIS in agriculture includes land use analysis, thematic mapping, demographic analysis, socio-economic studies and environment management [21].

A Global Positioning System (GPS) for better management of land and other resources for sustainable crop production as well as cultivation planning. Acquiring spatial data in GIS platform and remote sensing (RS) plays a major role in information management systems. RS is an accurate, efficient, economical and reliable technique to prepare a comprehensive inventory of the natural resources of a Sugar area [10].

New innovative IoT applications are addressing the issues in Sugar Factories and increasing the quality, quantity, sustainability, and cost effectiveness of sugarcane production. Technology, particularly the IoT technologies will play a fundamental role in improving sugarcane farming. The primary driver is the challenge of raising yields and different production costs, but this has many additional benefits in terms of more efficient labor and material costs. In Agricultural context IoT technology Addressed in Sugarcane Production Challenges to the use of sensors, cameras, and other devices to turn every element and action involved in farming into big data. Weather, moisture, plant health, mineral status, chemical applications, pest presence and much more can all to be turned into large data sets. IoT itself is not a product or particular tool, but one of a family of technologies. The aim of most agriculture IoT products is to enable Agriculturalist to use these insights to make operational decisions around planting, irrigating, harvesting and more [11].

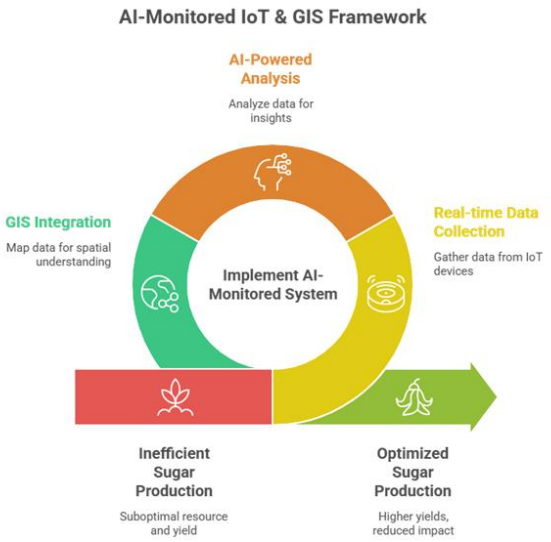

Fig 2: An AI monitored IoT & GIS framework within sugar industry.

The research know that farmer is the backbone of our country. There are lots of problems the research has been facing since independence. If the research needs to improve the quality of farming and economic condition of farmers, then the research should adopt Smart Agriculture systems. Above figure 2 proposes how the model can lead to an optimal solution for Farmers, Sugar Mills and its stakeholders using an AI monitored IoT and GIS systems [27].

To study of all these advanced IT tools and its impact using Artificial Intelligence implemented in Sugar industry will help us to obtain a detailed insights in Sugar mill and similar domains. It will also identify advanced IT systems has a positive and statistically significant effect on all directly and indirectly dependent persons, industry, area, community and hence State and Country [26].

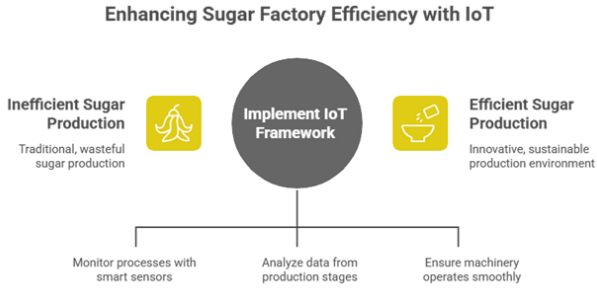

Fig 3: The IoT framework within sugar factory.

6. SIGNIFICANCE OF THE WORK

Most of the sugar industries are in operation with their traditional mostly manual systems. This has an impact on overall operations of the factories including troubles created to industrial units, management, its staff, and stakeholders [12].

An intelligent computer system with its knowledge, ITT, inference procedures along with AI will be beneficial to solve problems which are difficult for human expertise, yield, quality production, customer, dealers, and distributors satisfaction by

making them aware of the technologies and tools used in the industry leading sustainable economic growth and obvious growth of the industry [13].

As most of the industries use traditional systems, from their growth perspective, automation and use of technology is very significant. Overall interest and decision of management play vital role in adoption of these advanced technologies which makes industry financially sustained. So, while making this research aspect of management perspective is considered for supporting the use of technology, ITT, AI, benefiting industry and relevant factors. Most of the times studies are impacting business areas however, the desired research will have tremendous impact on social platforms. Some of the unknown results of these studies will obviously benefit social parameters of the community, identification of the ownerships of stakeholders and industries towards their social responsibilities. This study will benefit industries economically leading to enhancement in their social contribution towards CSR [12].

7. OBJECTIVES OF THE WORK

The study will focus on following objectives in the selected sugar factories:

- To develop an Information Technology Tools (ITT) framework using Artificial Intelligence monitored GIS and IoT systems to support optimality in Sugar industry resources.
- To test proposed Information Technology Tools (ITT) framework and do comparative analysis with old model in Sugar industries.
- To analyze the simulation results and to measure proposed model efficiency and productivity in Sugar industries.

8. HYPOTHESES OF THE PROPOSED WORK

Based on the review of literature and research questions identified the following hypothesis is derived:

H1: AI monitored GIS systems has significant impact on productivity improvement in Sugar industries.

H2: AI monitored IoT systems has significant impact on productivity improvement in Sugar industries.

H3: AI monitored GIS and IoT systems has significant impact on resources optimization process.

9. RESEARCH METHODOLOGY

9.1 Methods of research

An applied research design will be used in this study. The research design included identifying the practical problem that is set on providing practical solutions in the right directions, build a prototype and test whether the prototype meets desired functions with respect improving sugar industry's productivity [11].

Also, the research will use Structured Systems Analysis and Design Method (SSADM) for a rigorous system analysis, design, and development. It involved logical data, data flow and entity event modelling in a sub system.

9.2 Sampling design

A total of 20 sugar factories, 2 Lakh geo-locations will be considered for research across the Maharashtra State. 384 or more sugarcane plots (GPS locations) will be considered for sampling to have a confidence level of 95% that the real value is within ±5% of the measured/surveyed value. The techniques used to this research will non-Probability sampling that will be used to answers the research questions and objectives depends on research design. To generalize from a random sample and avoid sampling errors or biases, a random sample needs to be of adequate size. What is acceptable relies on many problems that sometimes annoy individuals conducting surveys for the first time. This is because what is important here is not the proportion of the sampled test population, but the absolute size of the chosen sample relative to the population's complexity, the researcher's goals, and the forms of statistical manipulation to be used in data analysis. While the larger the sample the lesser the likelihood that findings will be biased does hold, diminishing returns can quickly set in when samples get over a specific size which need to be balanced against the researcher's resources [21].

9.3 Conceptual framework-

Figure 4 gives an overview of the proposed methodology-

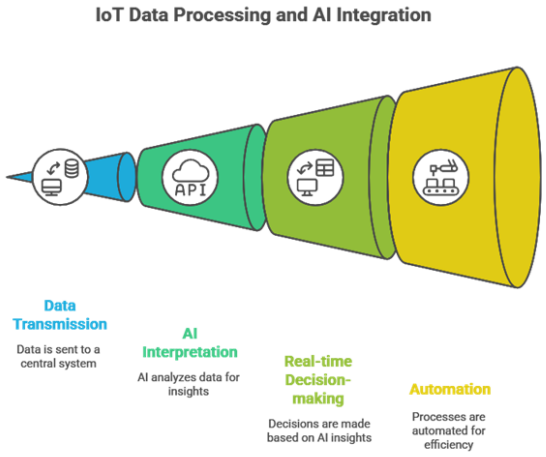

Fig 4: An overview of the proposed methodology.

The Research Methodology will consist of following steps:

Step 1 - Choose an objective to be evaluated. It could be profitability, productivity, growth etc.

Step 2 - Through a questionnaire and discussion with the executives of the factory prepare an exhaustive list of performance measures. This list gives the measures being used presently and additional measures which, in the opinion of the executives, should be included to measure the actual performance.

Step 3 - Gather data from the factory records (technical and financial) for the set of "measurable" performance indicators. Denote them R1, R2, R3, etc.

Step 4 - Identify the measure which is directly associated with the objective under consideration. It would be one of the overall measures of performance for the chosen objective.

Step 5 - Through Factor Analysis (FA) group R1, R2, R3, etc. into different factors.

Step 6 - Find the classifying values for this indicator through Delphi or Statistical techniques and group the data in these groups based on past performance.

Step 7 - Define the model as: Y = f (R1, R2, R3, Rn)

Step 8 - Use Multiple Discriminant Analysis (MDA) and find which of the indicators discriminate the groups.

Step 9 - The measures discriminating the groups are grouped into factors obtained in step 5.

Step 10 - The one ratio from each of the groups identified in step 9, which has the highest discriminating value by comparing "F to remove" values for discriminating variables. Alternatively, the research could select one ration from each of the groups with the highest loading on the factor.

Step 11 - Use MDA again with selected ratios in step 10 and get the classification results and compare with the results of the earlier analysis.

Step 12 - Se the set of ratios so obtained in a regression model to determine the values of the objective for a future time period.

Step 13 - Repeat from step 6 for other ratios which measure objective directly.

Step 14 - Compile the set of ratios related with the objective of the organization along with the importance due to them.

9.4 Research design

The nature of study will be an applied research design. In order to accomplish above objectives and to conduct this study, the required data was collected from primary as well as secondary sources which aim at studying the awareness of the Advance Information Technology implementation and innovative development awareness using Artificial Intelligence in selected Sugar Factories [22].

9.5 Methods of data collection

9.5.1 Primary data source:

Sugar Industries private GIS and IoT cloud connected systems.

9.5.2 Secondary data source:

To test the Productivity Impact Analysis from Artificial Intelligence monitored GIS and IoT data of Sugar Industries, researcher will need a corresponding data and datasets from already existing ERP systems and GIS public clouds. Through proper permission from respective authority of selected Sugar Factories, existing large datasets will be used to do research on above stated objectives. As researcher is working a Senior Manager in similar domain and having good number of experiences in similar industry so it is feasible to get required datasets from selected Sugar Factories for this research through proper permission. Other secondary data will be collected from, websites, magazines, textbooks and newspapers.

9.6 Methods of data analysis

The data collected from primary sources will be simulated and analyzed by using statistical and data analysis tools like Python, PANDA, MATLAB, SPSS etc. Descriptive Statistics, Inferential Statistics, Factor and Cluster Analysis will be used to justify above said objectives for this Research. Simulation of the proposed model will be carried with the help of MATLAB. To check the impact of productivity analysis, appropriate analysis tool will be used depending upon nature of available datasets from selected Sugar Factories for this study. The hypotheses were tested with the help of Chi-square test, paired student's t-test and factor analysis. Before Factor and Cluster analysis, the research needs to check consistency of collected data and available datasets. So, using Bartlett's test and Kaiser–Meyer–Olkin test data consistency will be checked. And after this test, Factor and Cluster analysis will be taken out and researcher will prepare simulative model of proposed framework.

9.7 Details of equipment's and instruments to be used and their source

R-programming using Python, SPSS, Microsoft Excel 2016 and Power BI software will be used for data analysis. Microsoft Visio-2016 will be used for drawing various diagrams. Descriptive Statistics, Inferential Statistics, Factor and Cluster Analysis will be used to justify above said objectives. Sign test, Chi-Square Test, t-test, Spearman's Test of Correlation will be used for data analysis and interpretation.

10. Conclusion

This research provides a critical framework for understanding the awareness, status, and operational dynamics of IT systems within the sugar industry. It moves beyond assessment to demonstrate concretely how advanced tools - specifically Geographic Information Systems (GIS) and the Internet of Things (IoT) powered by Artificial Intelligence (AI) - drive significant gains in efficiency and productivity. By leveraging these technologies, the industry can transition from traditional practices to data-driven decision-making, substantially reducing costs associated with manpower planning and resource allocation.

The broader impact of this technological integration extends far beyond immediate operational upgrades. The study highlights that the cost savings and efficiency gains from implementing AI-monitored systems enable stronger investment in Corporate Social Responsibility (CSR) initiatives, thereby benefiting the wider community. Ultimately, this adoption fosters sustainable growth for all stakeholders, positioning the sugar industry for a more efficient, profitable, and socially responsible future.

11. REFERENCES

[1] Tanha Talaviya, Dhara Shaha, Nivedita Patel, Hiteshri Yagnik, Manan Shah. "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides". Artificial Intelligence in Agriculture Volume 4, 2020. https://doi.org/10.1016/j.aiia.2020.04.002

[2] Pratibha M. Deshmukh, Dr. Pallavi P. Jamsandekar. "Transformation through Communication System the Step in Sugar Industries Domain". IJARCCE - Vol. 8, Issue 5, May 2019

[3] Mr. Ghule Kshitij Narendra and Dr. J.R Bhor. "E-HRM in Indian Sugar Industry: Differentiating Tool in Competitive Market". IBMRD's Journal of Management and Research, Print ISSN: 2277-7830, Online ISSN: 2348-5922

[4] Mrs.Varsha P.Desai, Dr. R.D. Kumbhar. "Impact of ERP Implementation on Performance of Private Sugar Factories in Sangli District". IRJMS Vol. 4, Special Issue 8, February, 2018 ISSN (Online): 2454-8499

[5] R. Kumar and V. Nath, Int. J. Logistics Systems and Management, Vol. 35, No. 1, 2020

[6] S S Hasan, P K Bajpai, Rajesh Kumar, S N Singh And A K Sah "Information and Communication Technologies tools for effective management of data in sugar mill zone" (Indian Journal of Sugarcane Technology 2011 26(1): 55-59)

[7] Hukwunonso Franklyn and Aisha Tukur. "Problems And Prospects Of Adopting Ict In Agriculture". African Journal of Agricultural Research and Development, Volume 5, Number 3, 2012 ISSN: 2141-0097

[8] K Asha, Mamatha K, Ashwini S Patil. "Providing Smart Agricultural Solutions to Farmers for Better Yielding using IoT". ICACT - 2016 (VOLUME 4 - ISSUE 22)

[9] Artificial Intelligence – Achyut Godbole, Madhushree Publication, Marathi , ISBN-13 : 978-8195377275

[10] Haridas B. Jogdankar and Minakshi V. Waykole. "Impact of Information Technology and Management on Sugar Industries". International Multidisciplinary Research Journal, ISSN No2231-5063, (Vol.4 Issue 6 Dec 2014)

[11] Business Research Method. Dr. Aditi Anant Kale, Dr. Rakesh Kumar Bhati, Dr. Anjum Sayyad, Thakur Publications

[12] Surabhi Singh, Santosh Ahlawat and Sarita Sanwal. "Role of ICT in Agriculture: Policy Implications" ISSN: 0974-6471, Vol. 10, No. (3) 2017, Pg. 691-697 www.computerscijournal.org

[13] Ritika Srivastava, Vandana Sharma, Vishal Jaiswal, Sumit Raj. "A RESEARCH PAPER ON SMART AGRICULTURE USING IOT". International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 07 | July 2020

[14] K Asha, Mamatha K, Ashwini S Patil. "Providing Smart Agricultural Solutions to Farmers for Better Yielding using IoT". International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Special Issue – 2016

[15] Modern Trends in Technology and relevant issues in cogeneration plants of Sugar Industry; https://cdm.unfccc.int/Projects/DB/SGS-UKL1200599187.35/ReviewInitial Comments/ 0E HRT I99IZO2F5EQWTHOTGXDFEKW14 as retrieved on 16 th March, 2017

[16] Dr. B. S. Sawant, Uma Jalindar Yadav "A Case Study: Problems and Prospects of IT Implementation in Sugar Factory", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 8, August 2012 ISSN: 2277 128X.

[17] Arundhathi, Suchit Nanda and Subbiah Arunachalam (2007). Transformative Impact of ICT Change Stories from Rural India. Jamsetji Tata National Virtual Academy (NVA) M S Swaminathan Research Foundation, Chennai 1-31. Available: www.mssrf-nva.org

[18] Sukhpal Singh (2004). Leveraging ICT for Agricultural Development: A case study of e-Choupals of ITC. Paradigm, Journal of IMT, Ghaziabad VIII(1) 1-6.

[19] Suresh Pal, Mruthyunjaya, Joshi PK and Raka Saxena (2003). Institutional Change in Indian Agriculture" National Centre for Agricultural Economics and Policy Research (Indian Council of Agricultural Research), New Delhi 1-445. Available: http://www.icar.org.in/ncap/index.htm.

[20] Venkatesh J, Sekar, Aarthy C, Balasubramanian M, Thenmozhi S and Balasubramanie P (2012). Role of ICT in Distribution of Knowledge in Agriculture Sector - Its Efficacy and Scope. The International Journal of Computer Science and Applications (TIJCSA) 1(5) 1-8.

[21] Anil Kumar, Hari Chand and D N Kamat. Artificial intelligence applications in sugarcane. Indian Farming 69(08): 03–04; August 2019. https://www.researchgate.net/publication/344643834_Indian_Farming_Artificial_intelligence_applications_in_sugacane

[22] N.N. Misra, Yash Dixit, Ahmad Al-Mallahi, Manreet Singh Bhullar, Rohit Upadhyay, Alex Martynenko. "IoT, big data and artificial intelligence in agriculture and food industry". DOI 10.1109/JIOT.2020.2998584, IEEE Internet of Things Journal.

[23] Muhammad Shoaib Farooq, Shamyla Riaz, Adnan Abid, Tariq Umer and Yousaf Bin Zikria. "Role of IoT Technology in Agriculture: A Systematic Literature Review."

[24] Dr. H K Shivanand, Puneeth P, MeghaShree K A. "Analysis on Application of GIS and GPS in Sugarcane Agriculture." Online ISSN: 2395-602X (www.ijsrst.com) doi : https://doi.org/10.32628/IJSRST207661.

[25] O.O. Obe and D.K. Shangodoyin. "Artificial Neural Network Based Model for Forecasting Sugar Cane Production". Journal of Computer Science 6 (4): 439-445, 2010 ISSN 1549-3636

[26] Ngozi Clara Eli-Chukwu. "Applications of Artificial Intelligence in Agriculture: A Review". Engineering, Technology & Applied Science Research Vol. 9, No. 4, 2019, 4377-4383

[27] Patrick Lukokoa, Charles Mundiab. "GIS Based Site Suitability Analysis for Location of a Sugar Factory in Trans Mara District". International Journal of Sciences: Basic and Applied Research (IJSBAR) ISSN 2307-4531.