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Conceptual Framework for Lean and Industry 4.0 Implementation in SMEs (Shuriken Framework)

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***Abstract:** This paper suggests a framework for implementing lean practices & Industry 4.0 technologies in the organization. This system can be potentially used in micro, small and medium enterprises. Industries have started paying attention to the Industry 4.0 phenomenon and researchers have identified that there is a strong inter-relation between Industry 4.0 and the lean practices. Many empirical researches have been conducted on these topics. Our paper attempts to bridge this gap explaining the correlation between the Industry 4.0 technologies and lean practices. Based on the analyses, we have proposed a framework that would help organizations understand the implementation of these practices collectively. The framework considers three core tenets- knowledge, resources and the level of implementation in any organization. Also, there are four core areas specifically to understand the process of implementation for the organization-lean practices, continuous improvement, Industry 4.0 and training programs for continuous learning. Such a presentation demonstrates the integration of these two paradigms in the entire supply chain.*

I. INTRODUCTION

Indian SMEs have been historically cash strapped and their economic viability leaves a lot to be desired to say the least. SMEs in India mainly service the core manufacturing sector in the country. The problem stems from here. SMEs in India have a huge competitive disadvantage as the bargaining power of buyers is pretty high. Added to that, the core manufacturing sector in India is highly limited to the automotive sector (ancillary units) and metal production (i.e steel, aluminum etc). As a result they are fairly cash strapped. This in turn leads to inertia in adoption of novel practices and technologies.

The benefits of adopting Lean manufacturing practices are extensively documented in famous use cases across industries. The most famous lean practices include, TPM (Toyota Production Management), TQM (Total Quality Management), Kanban, Poka-Yoke, 5S, JIT (just-in-time), Jidoka, Heijunka, Andon and VSM. The benefits of adoption of these practices are widely known, however the major problem of adoption is twofold, namely, a lack of awareness and understanding of lean practices and the lack of financial and manpower resources to implement these practices in SME systems. Our paper aims at solving one of these problems by addressing the gap between knowledge of lean practices and its implementation. We aim to provide a conceptual framework to address this gap and assist end users by giving them a guiding tool for implementing lean practices in their processes.

Industry 4.0 refers to a collection of technologies mainly dealing with automation and phasing out of tasks which required extensive human intervention. The basket of technologies involved in Industry 4.0 are IoT(Internet of Things), AI (Artificial Intelligence), ML (Machine Learning), RPA (Robotic Process Automation), Computer vision technology etc. Industry 4.0 uses the latest leapfrogs in technology made by companies all over the world in upgrading existing processes and capabilities.

Adoption of Industry 4.0 has a huge number of comprehensively documented benefits namely, faster production times, reduced dependence on human resources, improved quality, reduction of errors, higher precision products, shorter lead times etc. However, adoption of lean practices is a major challenge for most organizations particularly SMEs and especially in the Indian context. The major challenges being, a lack of knowledge and skills needed for the implementation of Industry 4.0 technologies, the problem of phasing out of old hardware and software and the retraining or laying off of existing employees if they fail to meet the skill requirements for the new technologies.

II. LITERATURE REVIEW

A. Lean Management

Over four decades have seen the application of the company technique known as lean management. The purpose of lean management is to find and get rid of waste. The Toyota Motor Corporation came up with the term. (Michael Sony, 2018)

Lean approaches have been extensively adopted and put into effect across a range of industries, with the broad expectation that doing so will enable businesses to realize some already established benefits.

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Four "bundles" of integrated and standardized processes are Just in Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM), and Human Resource Management (HRM). (Tommaso Rossi, Guido Orzes, Patrick Dallasega, Maria Pia Ciano, 2021)

In Japanese, "waste" is referred to as MUDA, and it is crucial to lean manufacturing.

According to Taiichi Ohno, these are motion, inventory, overproduction, overprocessing, and faults. The eighth waste, which was later popularized in the West, is human talent. (Michael Sony, 2018)

Different Lean visions have been put out by various authors. The term "Lean" became well-known from the book “The Machine That Changed the World” (Womack, Jones, and Roos, 1990)

Five concepts were introduced by the authors in their book "Lean Thinking" a few years later: value, value stream, flow, pull, and perfection (Womack and Jones, 2003). The first pillar stands for "just-in-time" production, which refers to manufacturing only what is needed at the precise moment when the end-user needs it. The second main principle is Jidoka, which refers to enhancing the quality of the final product by identifying process defects. The essential tenets of continuous improvement are waste reduction, collaboration among team members, and employees. Higher quality, lower prices, quicker cycle times, safety procedures, and great staff motivation are the final priorities at the top. (Samir Lamouri, Robert Pellerin, and Frederic Rosin, 2019)

Furthermore, lean thinking and training tools for lean are primarily aimed at introducing and motivating manufacturing companies to put into practice the lean concepts, whereby the objectives must be fully conceptualized, cross-functional teams are should be actively involved in value stream creation, and the schematic design is shifted along the value stream (Zayko et al., 1997; Womack and Jones, 2010).

This article's main objective is to study the connection between Industry 4.0 and lean manufacturing, as well as its performance implications and the environmental elements that affect these connections. Because of this, the first step is to develop a conceptual framework that describes the key constructs and how they relate to one another.

B. Industry 4.0

In order to significantly increase the efficiency of processes and the inflow and outflow of data for system analysis, Industry 4.0 encompasses a wide range of tools and technology as well as practices that can be applied in the manufacturing industries. The MSME sector is also greatly impacted by Industry 4.0, which transforms their current systems and procedures to increase efficiency. With support from the management and absorptive capacity (AC) strengthening relationships, small and medium-sized enterprises (SMEs) with stronger internal and external SC are more likely to adopt Industry 4.0 techniques. Investment in AMT in the manufacturing area and internal SC also have a positive correlation with the intensity of I4.0 adoption (Agostini L., Nosella A., 2019).

Due to a variety of factors, including a lack of resources, technical know-how, or simply lack of awareness, SMEs are hesitant to implement the wide range of Industry 4.0 technologies that are currently available on the market. The paper listed below provides proof for this. SMEs usually limit their use of cloud computing and the internet of things rather than maximizing the use of all the tools available for implementing Industry 4.0. Similar to this, it seems that SMEs have just recently embraced Industry 4.0 ideas for tracking industrial processes, and there are still no real-world applications in the field of planning for production (Moeuf A., Pellerin R., Lamouri S., Tamayo-Giraldo S., Barbaray R., 2018).

C. The relationship between Industry 4.0 and Lean Manufacturing

Lean practices are significantly impacted by Industry 4.0, as seen in the article below. According to the research, Jidoka and Industry 4.0 technologies enjoy strong support, whereas waste reduction and team and individual work receive little to no support. As a result, it is obvious that lean management must be continued, but some lean ideas must be improved with Industry 4.0 technologies (Rosin F, Forget P, Lamouri S, Pellerin R, 2020). An emphasis on "soft" lean practices, performance analysis of the integration of lean manufacturing techniques and Industry 4.0, and the environmental impact of the integration of Industry 4.0 and lean manufacturing are all necessary, as recommended by the study mentioned above. (Buer S. V., Strandhagen J. O., and Chan F. T., 2018)

As seen in the study below, there are numerous instances when industry 4.0 principles and lean practices are directly related to one another. This work illuminates a variety of previously unknown potential relationships between Industry 4.0 and Lean Practices. These connections include Statistical Process Control's empowering effects on Descriptive Analytics, Lean Layout's empowering effects on Autonomous AGV, One Piece Flow and JIT's empowering effects on Vertical Integration, and Autonomous Robots and IIoT's empowering effects on SMED and Standardized Work. (Ciano, M.P., Dallasega, G., and Rossi, 2021)

D. Research Objectives

To study the prevalence of Lean manufacturing practices, Industry 4.0 technologies and cyber-physical systems in Indian SMEs.
To develop a conceptual framework for the combined implementation of Lean practices and Industry 4.0 Technologies in an SME environment.

III. RESEARCH METHODOLOGY

A. Research on Existing Frameworks

There are a few studies done on Industry 4.0 and lean practices and various frameworks were suggested by these researchers. In order to get the lean and green supply chain, a model was developed which suggested that there should be close cooperation between the suppliers and better communication mechanisms such as hardwares as well as softwares should be adopted. This can be achieved by standardizing the interface and synchronization of data between the suppliers and the manufacturers. These factors are necessary for the Industry 4.0 paradigm which uses smart data that is highly driven by the different entities in the network. In manufacturing, the natural resources are put to optimum usage in the case of lean and green supply chains. Also, to understand the customer value and understanding the needs is the main concern of lean and green supply chains. This system has its main components revolving around the suppliers, customers, manufacturing units, recyclers and collectors. (Susana Duarte, V. Cruz-Machado, 2017). Another study has focused on the multidimensional analysis of operations management developing a conceptual framework of lean supply chain planning in Industry 4.0. The framework was based on the six main phases: visualization, analysis, conceptualization, modeling, validation, and proposal. And also, if necessary, corrective actions can be taken when there are any inconsistencies appearing in the model validation. The model also focuses on the risk management, lean manufacturing characteristics, technological structure and supply chain flows. (John Reyes, Josefa Mula, Manuel Diaz-Madronero, 2021)
Another study has proposed a framework that included various steps for the implementation of lean processes in an organization that contained: product value specifications, identification of value-creating activities, elimination of loss-making activities, scheduling the value-creating activities, value flow pull system and process optimization. (Adriana Florescu and Sorin Barabas, 2022)

B. Identification and Selection of Critical Practices and Technologies

Lean practices comprises various principles that are to be adopted by the organizations during the implementation of this paradigm. Collectively, these principles help in the implementation of Industry 4.0 technologies too. Some principles that are included in this framework are-
Total Quality Management is an approach to gain long-term success through maximum customer satisfaction. It focuses on improving the quality of products, services, processes, and culture of the organization.
Kanban is a Japanese term that refers to scheduling in lean manufacturing. It contains various cards or visual boards which help in managing the services by displaying the Kanban boards to maximize efficiency and improve continuously.
The 5S is a five step process for creating an organized and more productive workspace and stands for:sort, straighten, shine, standardize and sustain. The Just In Time principle focuses on the strategy that the organization should receive goods as they are needed and this increases productivity by reducing the time and resources involved in manufacturing processes.
Various technologies of Industry 4.0 that constitutes to the implementation of these paradigms are-
Artificial Intelligence helps the supply chains with smart decisions and help in performing various tasks for problem solving. It is automated by IIOT (Industrial Internet of Things) and can drive the entire supply chain without manual participation.
Machine Learning is used to process large volumes of input data and train the ML model. It helps to predict accurate data and train itself over the time period.
IoT (Internet of Things) helps the managers with better efficiency and connectivity of the vehicles in transportation with real-time tracking and there are equipment and devices used for real-time status updates on the jobs.

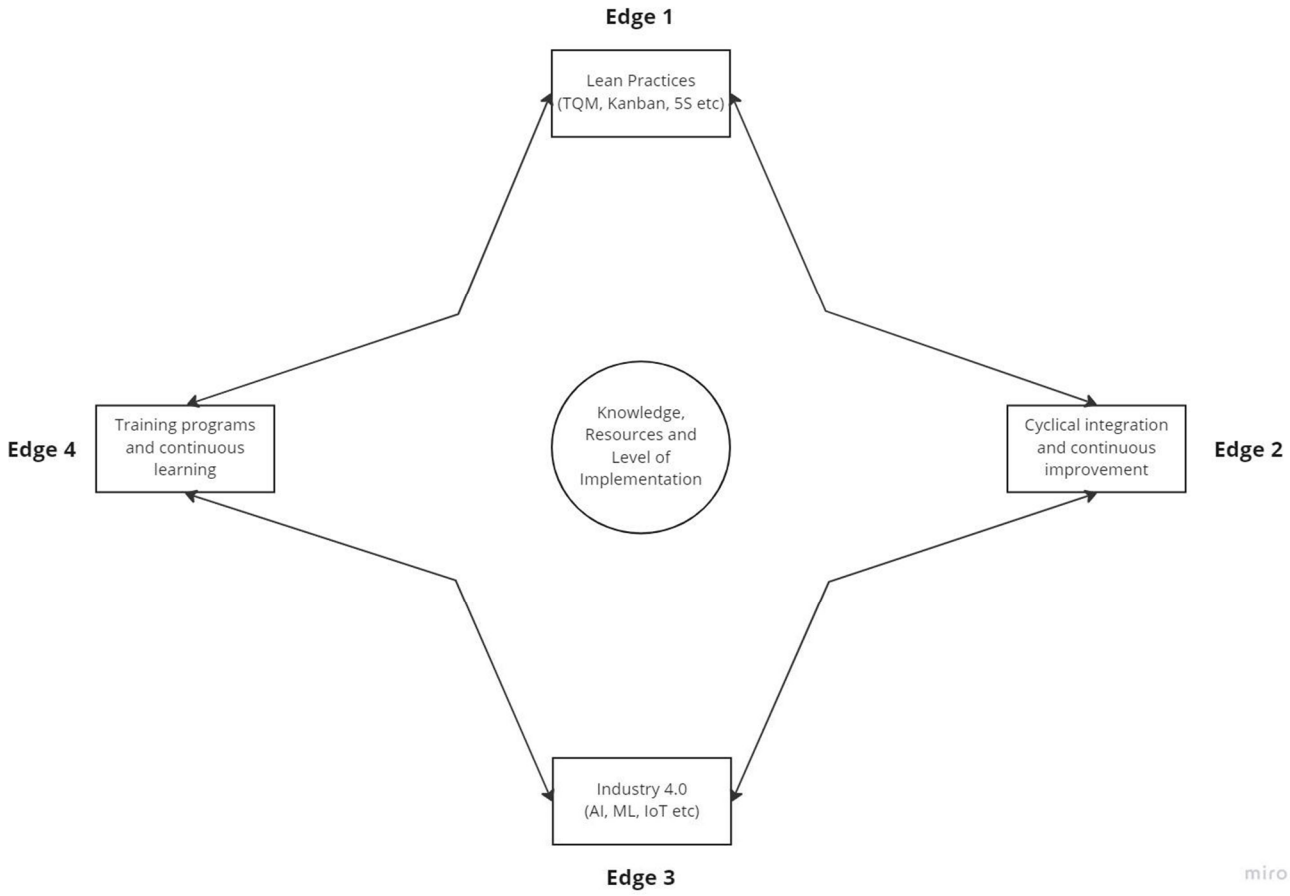
C. Developing a Model Framework for Implementation

Considering the existing models and framework, we have identified the gaps and proposed a framework for implementation of the combined paradigm in any organization. It consists of three main tenets i.e knowledge of the employees in an organization, resources-mainly financial and human resources, and the level of implementation. It has four dimensions-lean practices that focus on continuous improvement and cyclical integration, continuous integration and improvement, Industry 4.0 that continuously automates the process by the combination of hardware and software, training programs for the employees.

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IV. CONCEPTUAL MODEL



The conceptual model shown here demonstrates the implementation confluence of Lean Practices and Industry 4.0 technologies and how the implementation process would look like in an organization. The model revolves around three core tenets. They are knowledge of the practices and technologies, the resources to implement them and the level of current implementation in the organization.

V. CORE TENETS

A. Knowledge

To successfully implement lean and industry 4.0, the employees in an organization must possess a repertoire of knowledge of these topics to use the processes and technologies effectively themselves as well as guide the implementation process over the course of the project.

B. Resources

Resources refer to two items in particular, namely, the financial resources to buy the tools and technologies required for implementation and the human resources to implement them for which the previous tenet must be satisfied.

C. Level of Implementation

Modern organizations have already achieved some level of implementation of lean and industry 4.0 techniques however they must be gauged on the effectiveness of implementation and the current level of technology adopted. Measuring the efficiency of adoption is very important as it provides an overview and a reference metric for the company to follow in its implementation.

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1) Edge 1: Lean Practices

Lean practices refer to those practices that work on the five key lean principles namely, value, value stream, flow, pull and perfection. The lean practices that are based on these principles are 5S, Kanban, TQM, Jidoka etc. As can be seen in the diagram mentioned above, the flow of information goes from Lean practices to edge 2 which has cyclical integration and continuous improvements. Lean practices cannot be implemented at one go in any process or organization. It needs to go through several iterations of incremental additions before the processes start showing merit. For this to happen successfully, the knowledge and skills of the employees, resources for implementation and the measures for efficiency and effectiveness in adoption must be in place.

2) Edge 2: Continuous Integration and Improvement:

As mentioned earlier, the only way to ensure successful implementation is by practicing a system of continuous integration and improvement. Both of these concepts are borrowed from Agile Methodology. Continuous integration means incrementally adding the lean practices in cycles within each process. This ensures that the practices are not thrust on the employees at one go but rather they are exposed to it in steps and in increments. Continuous improvement will happen when the teams that implement these practices have regular retrospective meetings to decipher what went well, what went bad and what could be improved. By promoting a culture of retrospection, the organization ensures that the practices are implemented thoroughly and carefully. All of this again, can only be achieved with the help of proper knowledge, resources and measurement metrics.

3) Edge 3: Industry 4.0

As stated earlier, Industry 4.0 is a collection of tools and technologies that help automate processes by using a combination of hardware and software technologies to solicit information from sensors on the ground, process the data and present them for interpretation. AI and ML helps computers learn and understand from processes and implement changes in the processes on the fly. IoT makes use of sensors and microcontrollers to access real time data and use this data to monitor processes and implement changes. RPA (Robotics Process Automation), uses industrial robotics and smart factories to connect assembly lines across product verticals and reduce the overall dependence on human resources, thereby reducing errors and making processes more efficient.

4) Edge 4: Continuous Learning and Training Programmes

The major challenge with adoption of Industry 4.0 and lean practices is a lack of knowledge in many cases. As said, learning needs to be adopted in increments and the best way to do this is by having domain experts or coaches in every team to guide the team in correct implementation and to provide the team with a knowledge bank which they can exploit at their free will. As the team goes through various iterations of development the knowledge and skill sets will get added on incrementally and at the end of the process, the organization will be left with a team that is cross functional and filled with domain experts. In addition to these, the company can institute training programs to facilitate learning and development and make employees aware of the need for lean and Industry 4.0 tools and technologies. All of this is only possible with the availability of knowledge, resources and measurement metrics.

D. Social Implications

The social implications of the framework outlined in the paragraph may depend on how it is implemented in an organization. Here are a few potential social implications to consider:

1) *Job Displacement:* The implementation of lean practices and Industry 4.0 technologies could lead to some degree of job displacement, as some tasks may be automated or eliminated. However, it is worth noting that these technologies can also create new job opportunities, particularly in fields such as data analysis and AI development.
2) *Skills Development:* The adoption of Industry 4.0 technologies may require employees to develop new skills in order to use and manage these technologies effectively. This could have both positive and negative implications, as it may create new opportunities for learning and career advancement, but may also result in a skills gap for those who are unable or unwilling to learn these new skills.
3) *Data Privacy and Security:* The increased use of data-gathering technologies such as IoT could raise concerns about data privacy and security. It is important for organizations implementing these technologies to have strong data protection policies in place and to be transparent with employees and customers about how their data is being collected and used.
4) *Inequality:* There is a risk that the adoption of lean practices and Industry 4.0 technologies could exacerbate existing inequalities in the workplace, particularly if certain groups are more likely to be displaced by automation or less able to adapt to new technologies. It is important for organizations to be mindful of these issues and take steps to address any potential negative impacts

E. Business Implications

The business implications of the framework mentioned above are likely to be significant, as the implementation of lean practices and Industry 4.0 technologies can have a number of positive impacts on an organization.

Firstly, the adoption of lean practices can lead to improved efficiency and reduced waste in an organization's operations, as it focuses on streamlining processes and eliminating non-value adding activities. This can result in cost savings and increased profitability for the business.

Secondly, the incorporation of Industry 4.0 technologies such as artificial intelligence (AI) and the Internet of Things (IoT) can lead to increased automation and data-driven decision making, which can further improve efficiency and productivity. It can also enable the organization to access real-time data and make more informed, data-driven decisions, leading to improved operational performance and competitiveness.

Overall, the implementation of the framework outlined in the paragraph could lead to significant benefits for an organization, including improved efficiency, cost savings, increased competitiveness, and enhanced data-driven decision making

VI. CONCLUSION

In conclusion, the conceptual model presented in this paragraph outlines a framework for implementing lean practices and Industry 4.0 technologies in an organization. It consists of three core tenets - knowledge, resources, and level of implementation - and four core areas - lean practices, continuous improvement, Industry 4.0, and continuous learning and training programs. This model emphasizes the importance of knowledge, resources, and incremental implementation in achieving successful adoption of these practices and technologies, and highlights the role of continuous improvement in driving efficiency and effectiveness. By following this model, organizations can effectively integrate lean practices and Industry 4.0 technologies in their operations, leading to improved performance and competitiveness.

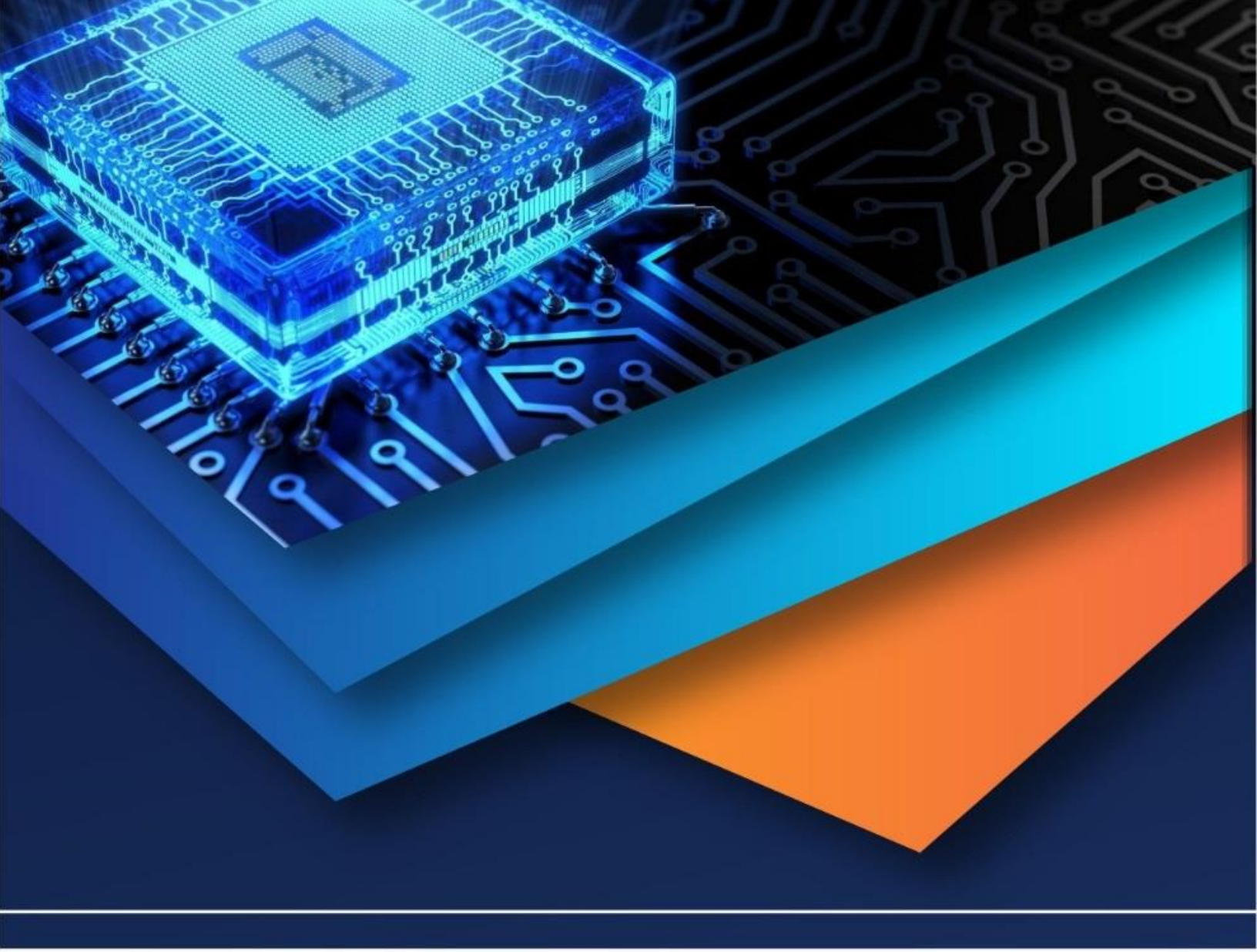
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