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Research Article

An Investigation into Revolutionizing Auto Component Manufacturing: An IoT-Based Approach for Improved Productivity and Waste Elimination

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ABSTRACT

The Auto Component Manufacturing industry is confronted with numerous challenges pertaining to productivity, waste reduction, and operational efficiency on the shop floor. Conventional manufacturing processes often prove to be time-consuming, resulting in substantial waste generation, leading to elevated production costs and heightened environmental concerns. In response to these issues, the adoption of an IoT-based approach presents a promising solution for enhancing manufacturing efficiency and sustainability. This research paper delves into the realm of IoT implementation within the Auto Component Manufacturing sector. The primary objective is to explore case studies, identify bottlenecks in existing processes, and examine the outcomes of these case studies. By focusing on real-world examples, we aim to shed light on the practical applications and benefits of integrating IoT technology into the manufacturing landscape. One novel aspect of this study is the holistic implementation of a Whole IoT enterprise that spans from suppliers to end customers within a company. This comprehensive approach has seamlessly connected various departments and led to a significant reduction in waste generation across the supply chain. Through the integration of IoT technology, companies gain access to real-time insights into their production processes and equipment. This invaluable data empowers them to make informed, data-driven decisions promptly, resulting in substantial cost savings and enhanced operational efficiency. The findings presented in this paper underscore the potential of IoT-based solutions to revolutionize traditional manufacturing practices in the Indian Auto Component Manufacturing industry. In conclusion, this research paper not only discusses case studies to uncover operational bottlenecks but also showcases the tangible outcomes of IoT implementation. By offering a comprehensive view of the scope of IoT integration and its transformative impact, this paper underscores the potential for achieving greater efficiency, cost savings, and sustainability within the Auto Component Manufacturing industry through IoT technology.

Keywords: Smart Manufacturing, Industry 4.0, Data analytics, Predictive maintenance, Lean manufacturing, Interconnected IoT departments

1. INTRODUCTION

The implementation of IoT technology in the manufacturing industry has the potential to revolutionize the way businesses operate. By enabling real-time monitoring, data analysis, and automated decision-making, IoT can help businesses achieve significant improvements in productivity, quality, and cost efficiency Zhang, Y et al. [1]. One of the biggest challenges is the integration of IoT devices and systems with existing production processes and legacy equipment. Additionally, the security and privacy concerns associated with IoT devices and data management must also be addressed. In the context of the Indian Auto Component Manufacturing industry, the challenges and opportunities associated with IoT implementation are particularly relevant Kamble,S.S et al.[2]. The industry faces intense competition from global players, increasing pressure to reduce costs and improve quality, and growing demand for sustainable and environmentally friendly manufacturing practices. By leveraging IoT technology, the industry can potentially address these challenges and achieve significant improvements in productivity, waste elimination, and sustainability Torres, D et al. [3]. The proposed investigation aims to address these issues by conducting a comprehensive investigation into IoT-based approaches for improved productivity and waste elimination in the Indian Auto Component Manufacturing industry. Analyzing the existing problems and losses in shop floor activities and identify the potential benefits and limitations of IoT implementation. It also explores the best practices for IoT integration in the manufacturing environment, as well as the key factors for successful IoT implementation. This investigation contributes to the development of a road map for IoT-based approaches in the Indian Auto Component Manufacturing industry and provides recommendations for businesses seeking to implement IoT technology. Frank, A.G et al. [4] identified challenges in implementing an IoT-enabled predictive maintenance framework for the automotive industry, such as data quality and reliability issues, high maintenance costs, and the need for a skilled workforce to handle the technology. Wang, X et al. [5] discussed the challenges of implementing Industry 4.0 based smart manufacturing using IoT for automobile component manufacturing, including data security concerns, interoperability issues, and the need for training and education of the workforce. Dhone,NC et al. [6] identified challenges in implementing Industry 4.0 and smart manufacturing, such as the need for significant investments in technology and infrastructure, data privacy and security concerns, and the need for new business models and organizational structures. Tao, F et al. [7] discussed challenges in implementing IoT in the automotive industry, including the need for standardization of data and communication protocols, the high cost of IoT sensors and devices, and the need for a skilled workforce to handle the technology. Alenezi, M et al. [8] identified challenges in implementing the interconnected IoT departments, conceptual idea of the implementing the Interconnected IoT departments, however it possesses lot of setbacks over there because installation of IoT in all the departments may leads to huge initial investment. Kolla, S.S.V.K et al. [9] discussed the challenges of converting the traditional legacy machines into the IoT enabled machines, several types of alterations needed in the machines to convert that as the IoT enabled machines and that consumes more time and that is not economically feasible. Rathod, N. [10] identified challenges in implementing IoT-enabled industrial setup, IoT enabled devices functions effectively when it is equipped with the High network connectivity, if companies are located in the rural area or where network connectivity is poor, ultimately performance of the machineries gets declined and that results in the productivity loss. Asif, A.A et al. [11] discussed the challenges of implementing IoT-based condition monitoring and predictive maintenance in the automotive industry, including the need for a large amount of data to train machine learning models, the need for skilled personnel to develop and maintain the models, and the need for a standardized data communication protocol. Shiue, Y.R. et al. [12] discussed the challenges of implementing IoT-enabled supply chain management in the automotive industry, including the need for a standardized data communication protocol, data privacy and security concerns, and the need for a skilled workforce to handle the technology. Chien, C.F et al. [13] identified challenges in implementing IoT-enabled quality control in the automotive industry, including data quality issues, the need for standardization of data and communication protocols, and the need for a skilled workforce to handle the technology. Several research gaps can be identified. While many studies focus on the challenges of implementing IoT in the automotive industry, there is limited research on the integration of various Industry 4.0 technologies. Additionally, most studies emphasize the need for a skilled workforce to handle the technology, but there is limited research on the specific skills and training required. There is also a lack of research on the cultural and organizational changes required to implement Industry 4.0 technologies successfully. Furthermore, although data quality and security concerns are identified as significant challenges, there is a lack of research on specific strategies to address these issues. Finally, while many studies discuss the need for standardization of data and communication protocols, there is limited research on the practical implementation of these standards in the automotive industry. So, by analyzing these research gaps that trying to sort out the all these short-comes and want to implement best practices in the industry to maximize the productivity.

1.2. Problem Statement

The Indian auto component manufacturing industry faces several challenges, including low productivity and high levels of waste, which negatively impact profitability and sustainability. Traditional manufacturing processes rely on manual labor and limited monitoring systems, which often lead to inefficiencies and waste [14]. There is a need for a more innovative approach to address these challenges and enhance the competitiveness of Indian auto component manufacturers. This investigation aims to address this problem by exploring the potential of an IoT-based approach to revolutionize the manufacturing process, improve productivity, and eliminate waste.

1.3. Motivation

The motivation behind this investigation is to address the challenges faced by the Indian auto component manufacturing industry and explore innovative approaches to enhance its productivity and sustainability. The industry plays a crucial role in the Indian economy, providing employment to millions of people and contributing significantly to the country GDP. However, the industry faces several challenges, including low productivity and high levels of waste, which impact its competitiveness and sustainability [15]. By leveraging IoT technologies, this investigation seeks to identify new opportunities for optimizing manufacturing processes and enhancing the industry efficiency and sustainability. The potential benefits of this investigation include improved productivity, reduced waste, cost savings, and a cleaner and safer work environment for employees. The findings of this investigation could have significant implications for the Indian auto component manufacturing industry and provide a roadmap for other manufacturing industries to leverage IoT technologies to enhance their efficiency and sustainability.

2. PROPOSED METHODOLOGY

In this investigation, proposed methodology is IoT-based approach to improve productivity and eliminate waste in the Indian auto component manufacturing industry. To achieve this, Researcher should conduct a mixed-methods research design that combines both qualitative and quantitative data collection techniques [16]. Firstly, conduct a comprehensive literature review to gain a thorough understanding of the current state-of-the-art in IoT-based manufacturing systems and their potential applications in the auto component manufacturing industry. Next conduct a series of semi-structured interviews with key stakeholders in the Indian auto component manufacturing industry, including industry experts, manufacturers, and suppliers. The interviews are designed to gather information on the current state of manufacturing practices, challenges faced by manufacturers, and the potential benefits and drawbacks of implementing IoT-based solutions. In addition to interviews also collect quantitative data through the use of surveys and observation. Surveys are distributed to a sample of employees within the manufacturing plants to assess their knowledge and attitudes towards IoT-based systems. Observations are conducted in the manufacturing plants to assess current processes and identify areas for improvement. Finally Analyze the data collected through these methods using both qualitative and quantitative analysis techniques, including content analysis, thematic analysis, and statistical analysis. This analysis is used to identify key findings and recommendations for the implementation of IoT-based solutions in the Indian auto component manufacturing industry.

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3. SCOPE OF IOT INTEGRATION

The scope of IoT integration serves as a comprehensive framework that meticulously defines the parameters, goals, and processes involved in incorporating Internet of Things (IoT) technology into a particular context, whether it's an industry, organization, or project. It encompasses a multifaceted approach to elucidate the fundamental aspects of the integration endeavor. The document commences with a purposeful title and an insightful introduction that articulates the rationale for embarking on an IoT integration journey, setting the stage for a deeper understanding of its significance. Within this scope, the core objectives and goals are meticulously outlined, providing an unambiguous articulation of the overarching intent behind adopting IoT technology. These objectives serve as guiding beacons, illuminating the path toward the desired outcomes, which could encompass anything from enhanced efficiency and cost reduction to improved customer experiences and competitive advantage. Clarity is paramount in this section to ensure that all stakeholders share a common vision of what success entails. Crucially, the scope of IoT integration defines the boundaries of the project. It explicitly states what falls within the purview of the IoT integration initiative and, equally important, what remains excluded. This delineation is vital for managing expectations, avoiding scope creep, and maintaining a focused approach throughout the project's lifecycle. It may encompass geographical boundaries, functional domains, and organizational divisions to provide a holistic view of the initiative's extent. Furthermore, a key facet of the scope is the identification and characterization of stakeholders. These individuals or groups play pivotal roles in the IoT integration journey. Each stakeholder's involvement, responsibilities, and expectations are meticulously elucidated to ensure a harmonious and collaborative approach. This detailed stakeholder analysis fosters accountability, effective communication, and a shared sense of ownership, which are essential for successful IoT integration. In essence, the scope of IoT integration acts as a guiding compass, meticulously defining the who, what, why, and where of the integration initiative. It sets the stage for strategic planning, execution, and management by offering a granular and comprehensive view of the undertaking's scope, objectives, and participants. This document serves as a foundational reference point, facilitating effective decision-making, project governance, and the realization of the anticipated benefits of IoT integration.

The scope of IoT implementation in Indian auto component manufacturing enterprises is vast, and it can be applied to various aspects of the manufacturing process. IoT can be used for asset management, supply chain optimization, predictive maintenance, and quality control. Detailed explanation of each aspect is given below

3.1. Asset Management: IoT sensors can be installed on machinery and equipment to track their performance and health [20]. These sensors can collect data on parameters such as temperature, vibration, and energy consumption, which can be used to identify potential issues before they cause any downtime.

3.2. Supply Chain Optimization: IoT can be used to track the movement of raw materials, work-in-progress, and finished products within the manufacturing facility.

3.3. Predictive Maintenance: IoT sensors can be used to monitor the condition of machinery and equipment and predict when maintenance is required.

3.4. Quality Control: IoT can be used to monitor the quality of products during the manufacturing process. Sensors can be used to measure parameters such as dimensional accuracy, surface finish, and material composition. Basic block diagram of an IoT implementation in an auto component manufacturing enterprise and is shown in Fig.-5.

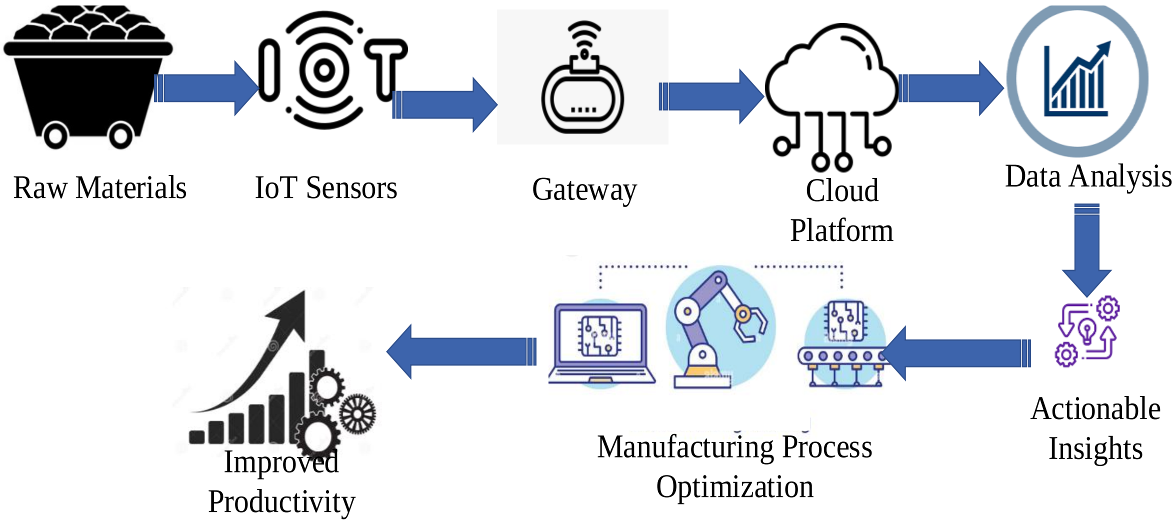

Figure 1: Scope of IoT Implementation in Auto component Manufacturing Industries

In this above diagram, IoT sensors are installed on raw materials, machinery, and finished products. The sensors collect data and send it to a gateway, which then sends it to a cloud platform for storage and analysis.

4. CASE STUDIES FOR THE INDIAN AUTO COMPONENT INDUSTRIES

Case studies are indispensable tools for the Indian auto component industry due to its intricate market dynamics, globalization aspirations, and the need to navigate regulatory changes effectively. This industry operates in a competitive environment, with evolving consumer preferences and technological advancements. Case studies provide a deep dive into real-world scenarios, enabling stakeholders to adapt and excel in this dynamic landscape.

Additionally, as the industry aims to expand globally, case studies shed light on successful export strategies and insights into overcoming international market challenges. In summary, case studies are essential for the Indian auto component industry to glean practical wisdom for sustainable growth and global expansion.

4.1. Case Study 1

ABC Industry is a prominent automotive component manufacturer headquartered in Pune, India. With a foundation dating back to 1990, the company has grown into a global player in the automotive industry. They specialize in producing a wide range of components and systems for various vehicles, including motorcycles, passenger cars, commercial vehicles, and electric vehicles. One of their notable product lines is exterior lighting systems, where they excel in manufacturing headlamps, taillamps, fog lamps, and other illumination products. ABC Industry is also known for its expertise in electrical and electronics components, providing instrument clusters, sensors, electronic control units (ECUs), and other essential parts used in vehicle systems. Another significant area of focus for ABC IndustryGroup is engine components. They supply various products like air intake systems, engine covers, and other engine-related parts that enhance performance and efficiency. Moreover, the company caters to the aftermarket segment, providing replacement parts and accessories worldwide. Setup of IoT enabled press shop is shown in Fig.-2.

4.2.1. Framework of IoT Integration in Assembly Shop

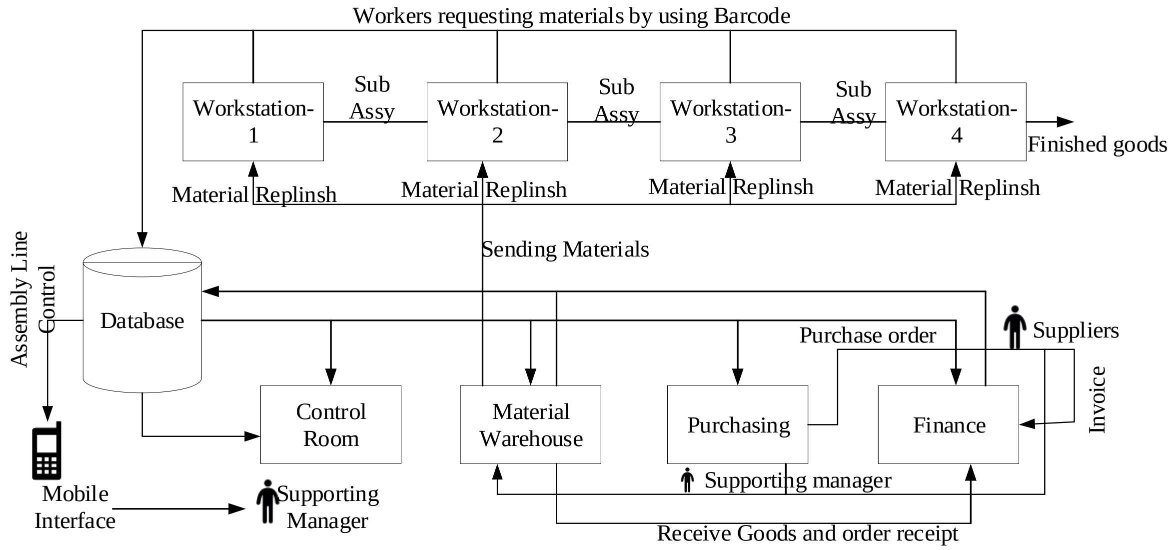

Figure 2: Framework of IoT Integration in assembly shop

Quality control is enhanced through IoT sensors, minimizing defects and waste. Inventory management is improved with real-time visibility and efficient stock management. Worker safety is enhanced through wearable devices and ergonomic risk detection. Overall, IoT revolutionizes operations, driving efficiency, cost reduction, product quality improvement, and a safer work environment, enhancing industry competitiveness. Challenges and solutions are Implementing IoT in the assembly shop of the Indian Auto-component manufacturing industry poses challenges that need to be addressed for successful deployment. Connectivity and network infrastructure requirements must be met through scalable and reliable solutions. Integration with legacy systems and equipment can be achieved with suitable integration solutions. Data security and privacy measures, such as encryption and access controls, are crucial. Workforce training and acceptance of IoT technologies are important for successful adoption. Addressing these challenges ensures a smooth transition and maximizes the benefits of IoT technology in the assembly shop. Outcomes and benefits of the assembly shops are Implementing IoT in the assembly shop of the Indian Auto-component manufacturing industry brings significant outcomes and benefits.

4.2.2. Before IoT data logging Process – Assembly Shop

Before the integration of IoT data logging processes in an assembly shop, operations relied on traditional manual methods for data collection and management. In this context, workers were responsible for manually recording information such as machine operating parameters, production counts, and quality checks. This process was time-consuming, prone to human errors, and lacked real-time insights. Communication between different stages of assembly and across teams was often fragmented, leading to delays in identifying issues and responding to changing conditions. Without IoT-enabled data logging, the assembly shop operated with limited visibility into the status of machines, equipment, and workstations. Predictive maintenance was challenging, as there was no automated way to monitor the health of machinery or detect anomalies before they caused disruptions which is shown in Fig.-3. Quality control and compliance checks relied heavily on manual inspections, which could result in inconsistencies and quality deviations

Production Date		Shift				Die Start	Die End		Production (Assembly)				Dow Availability Planned DT			.	Break Down Losses (AB)			Changeover losses(AC)			Unavailability of Resour (AW)				
													TB	BF	LB	AP	AB01	AB02	AB03	AC01	AC02	AC03	AW01	AW02	AW04	AW05	AW
Date (Month / Day)	Assembly Line	Shift	Line Leader	Shift Incharge	Assembly number	Time (HH : MM)	Time (HH : MM)	Actual running SPM	Total Assembly	Rework	Rejection / Scrap	Accepted - Good Strokes / Parts	Tea Break	Break Fast	Lunch Break	Power Failure	quipment/Machine	Fixture/Die/Tool	Automation / Gripper (WHD)	lanned Changeover	planned Changeover	Coil Change	Manpower Unavailability	Raw Material Unavailability	Logistics/ Transportataion uipment Unavailability	iting for QA Decision	Unavailability of RM due
25-Mar	G2	A	VS	SK	6R4.831.507/508.B	6:30	8:55	7.10	475			475						32									
25-Mar	G2	A	VS	SK	0201EAL00620N	8:55	10:35	7.50	414			414									15						
25-Mar	G2	A	VS	SK	0401BBB00300/550N	10:35	14:24	6.10	486			486					70				10						
25-Mar	G2	A	VS	SK	541261308222/23	14:24	15:00					0						4			10						
25-Mar	G2	B	VY	CP	541261308222/23	15:00	17:00		151		43	108					20	45								5	
25-Mar	G2	B	VY	CP	42590485	17:00	19:30		643			643						24		16						5	
25-Mar	G2	B	VY	CP	0201EBC00250/290N	19:30	22:10		338			338						29		20						5	
25-Mar	G2	B	VY	CP	541231608260/67	22:10	23:30		58			58								25						5	
25-Mar	G2	C	AB	SM	541231608260/67	23:30	0:50		17			17						49									
25-Mar	G2	C	AB	SM	95158899 (FDI RH)	0:50	3:50	8.50	998			998						13		22							
25-Mar	G2	C	AB	SM	0208AAL01010/20N	3:50	6:30	6.10	172			172					63	31									
26-Mar	G2	A	VS	SK	0208AAL01010/20N	6:30	7:30	5.50	36			36						26	9								

Figure 3: Before Data logging process – Assembly shop

Overall, the absence of IoT data logging in the assembly shop hindered operational efficiency, decision-making, and the ability to capitalize on optimization opportunities. It also limited the shop's capacity to adapt to dynamic production requirements and maintain a competitive edge in the rapidly evolving industrial landscape.

4.1.3. Challenges

As a part of their Industry 4.0 initiative, the customer primarily wished to leverage IoT for maximizing operational efficiencies, productivity, reducing the energy footprints and maximizing capacity utilization. But there were several challenges at the outset:

• Firstly. the customer had multiple assembly lines with a diverse set of machines. systems and sensors, all communicating on different protocols. As such, primarily they needed a partner who could connect diverse set of assets on to a single platform and make use of underutilized 'dark' data.

• Secondly, the amount of data, data types and their applications was so vast, that the platform handling it, needed to be scalable and flexible.

• Lastly, ABC Industry faced the typical challenge of innovating in 'Brownfield' markets - wherein the real bottleneck is in integrating loT in tandem with both the new and legacy equipment without any further CAPEX for asset substitution.

4.1.4. Solutions

Company adopted an IoT integration strategy to bridge technology gaps and enhance their industrial IoT capabilities. They leveraged a scalable cloud-based IoT platform, which leveraged OPC as the connectivity standard. This platform securely collected data from a diverse range of assets and various operational technology (OT) sources, including PLCs, sensors, CNC controllers, relays, HMIs, and CSV files, located across different sites and using different protocols. The chosen IoT platform, referred to as the platform, processed this data in real-time through an OPC client (agent), interpreting the data stored in tags within the OPC server client. This deployment allowed machines and systems to stream real-time data to the centralized IoT platform within a few weeks. The platform harnessed this data, along with data from human-machine interface (HMI) screens where operators logged supplementary information such as downtime codes. These inputs were used to track downtime, improve uptime, and calculate "mean time to resolve."

Furthermore, the IoT platform seamlessly integrated with modern web and mobile applications through a range of REST APIs. This facilitated the injection of production data into various systems, including ERP systems like SAP, and enabled the development of custom applications to present data in a user-friendly manner on any device. Importantly, this integration required minimal changes to existing workflows and did not disrupt operator activities. The flexible pricing model of the platform allowed customers to pay only for the connected machines, eliminating the need for significant upfront investments. Additionally, the platform provided a guaranteed uptime service level agreement (SLA), ensuring data processing and system availability. Outcomes are listed below

4.1.5. Bottlenecks

Press machines operating without IoT integration experience a series of limitations. Firstly, they suffer from a lack of real-time visibility, making it challenging for operators and managers to monitor the machine's status and performance promptly. This absence of instant data leads to a reliance on manual data collection processes, which are not only time-consuming but also prone to human errors. Maintenance practices become reactive rather than proactive, resulting in unexpected downtime and increased operational costs. Moreover, without IoT, these machines miss out on the predictive analytics capabilities that can forecast potential issues, optimize performance, and enhance overall efficiency. In summary, the absence of IoT integration in press machines can impede productivity, increase operational costs, and hinder the ability to make data-driven decisions for process improvement.

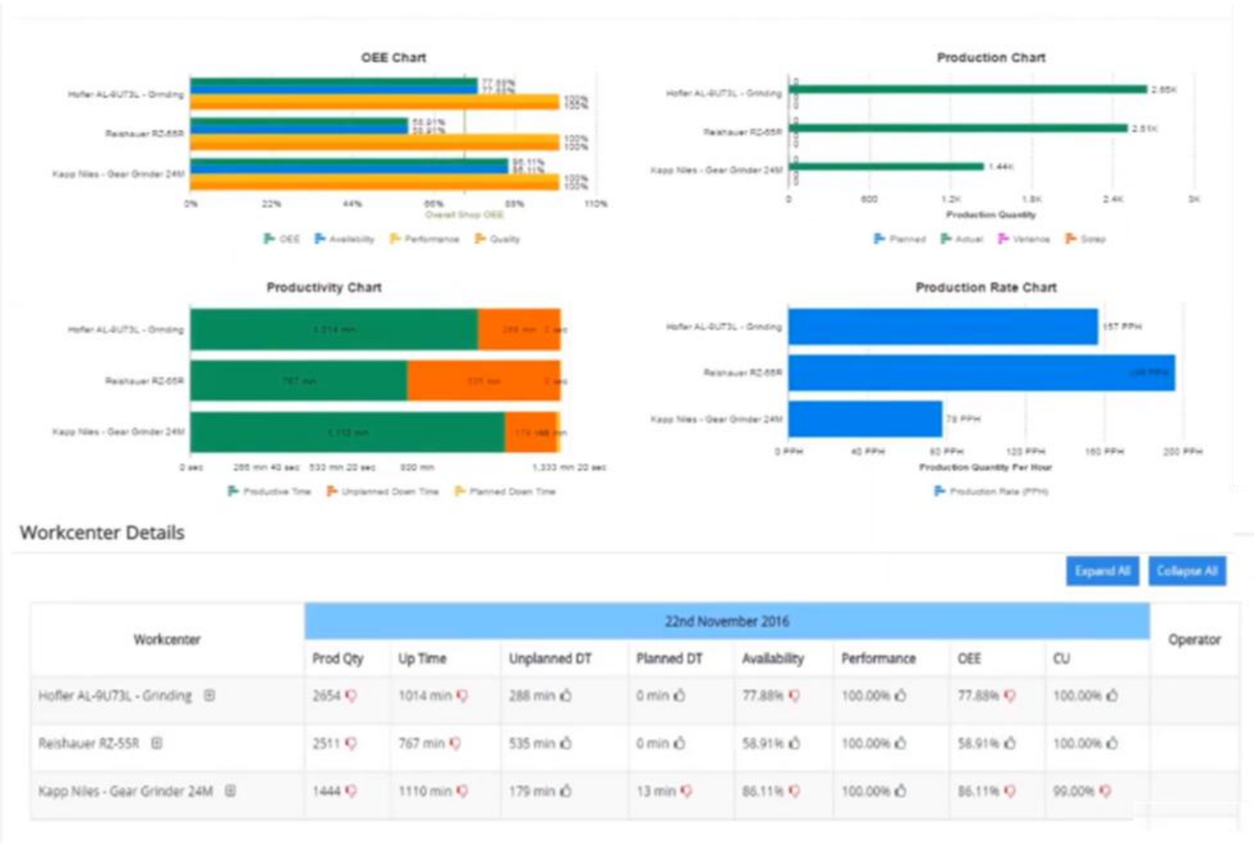

Figure 4: Bottlenecks of Press Machine

4.1.5.1. Overcoming the Bottlenecks

To overcome the bottlenecks faced by press machines lacking IoT integration, a proactive approach is essential. Start by implementing IoT integration, equipping the machines with sensors and connectivity to collect real-time data on crucial parameters like temperature, pressure, and performance metrics. This data is then transmitted to a central system for analysis. Embrace predictive maintenance, leveraging the IoT data to anticipate issues before they cause downtime or damage. By identifying maintenance needs in advance, you can reduce costs and extend the machine's lifespan. Additionally, automate data collection to eliminate human errors and enhance efficiency. This streamlined data allows for more informed decision-making and optimized resource allocation. Overall, integrating IoT technology empowers press machines to operate at peak performance while minimizing downtime and operational inefficiencies.

4.1.6. Machine Health Monitoring

Machine health monitoring of a press shop with IoT involves the implementation of Internet of Things technology to continuously assess and optimize the performance of press machines within the shop.

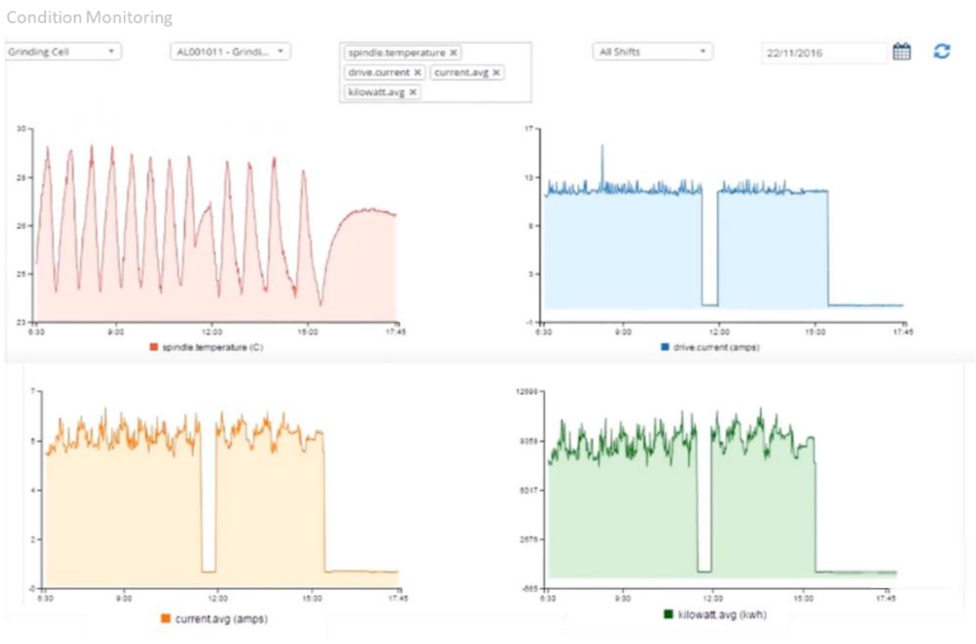

Figure 5: Machine Health monitoring - IoT Enabled

By equipping these machines with sensors and connectivity, real-time data on variables such as temperature, pressure, vibration, and operational efficiency can be collected and transmitted to a centralized system. This data is then analyzed to provide valuable insights into the health and condition of each machine. Through predictive analytics, potential issues and maintenance needs are identified in advance, allowing for proactive maintenance and minimizing costly downtime. Machine health monitoring with IoT not only enhances operational efficiency but also extends the lifespan of equipment, reduces maintenance costs, and ultimately ensures a smoother and more productive press shop operation.

4.1.7. Machine Real-Time OEE, Production, And Productivity of Press Shop

Implementing real-time Overall Equipment Effectiveness (OEE) monitoring, production tracking, and productivity optimization in a press shop through IoT (Internet of Things) integration is a transformative approach. By deploying IoT sensors and connectivity on press machines, the shop gains the ability to continuously monitor and calculate OEE metrics in real-time.

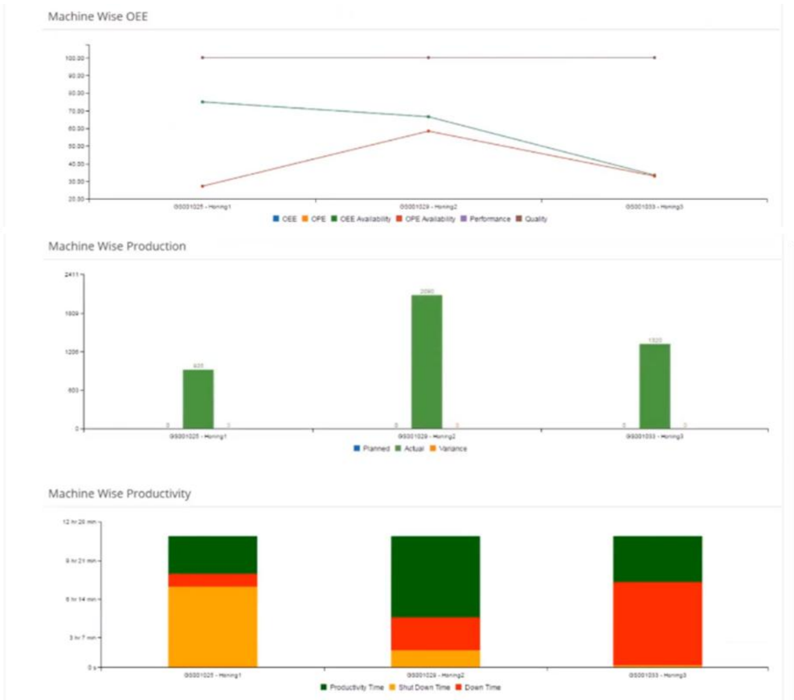

Figure 6: Machine Real-Time OEE, Production Real time dashboards.

This includes measuring factors like machine availability, performance efficiency, and quality of output. Moreover, IoT enables the tracking of production progress, providing insights into production rates, downtime reasons, and overall equipment health. Armed with this data, operators and managers can make informed decisions to maximize productivity, reduce inefficiencies, and proactively address maintenance needs. Ultimately, this integration empowers the press shop to operate at peak efficiency, meet production targets, and maintain a competitive edge in the manufacturing industry.

4.1.8. Outcomes

When implementing IoT with the Press machines, enormous outcomes we can achieve., Outcomes are as follow

4.1.8.1. Centralized Machine Data

Centralized machine data, an outcome of IoT-enabled press machines, consolidates real-time information on machine health and performance in one location. This centralized repository allows for efficient monitoring of all press machines, enabling proactive issue identification and preventing downtime. It facilitates data analysis for performance reports and informed decision-making, ultimately optimizing production efficiency and reducing operational costs.

4.1.8.2. Monitoring and Maximizing Line Efficiency

OEE (Overall Equipment Effectiveness), OPE (Overall Process Effectiveness), Production Variance, Accurate Idle time pockets & Reasoning could now be monitored at cell, machine and/or plant levels in near real time. Providing Production Visibility and Machine Efficiency across assembly lines allowed decision makers to monitor progress at a plant level and drill down into specific machines whenever needed.

1. Due to the reduction in shifts, OEE has seen a considerable improvement which has led to an almost n% increase in Operational Efficiency and 10% reduction in direct running costs of the machine (including labor and energy)

2. Insights into real time OEE and downtime, have also reduced the number of people employed in data entry of these metrics. The indirect manpower reduction has helped to the tune of 20% increase in Manpower Efficiency.

4.1.8.3. Condition Monitoring

Systematic processes (alerts & notifications) could be created to identify the Idle time pockets that can now never be missed. Alerts triggered as per escalation plan based on business process requirements. Further Condition monitoring and a tool health dashboard ensured that the tool consumption and inventory was reduced by 2% leading to a considerable working capital reduction.

4.1.8.4. Energy Monitoring

Energy meters were connected for consumption monitoring at machine, cell, and plant levels, resulting in a significant improvement in energy management. This implementation allowed us to efficiently manage energy requirements for current operations and plan for future scale-up, ultimately leading to a reduction in energy consumption by approximately 15%.

4.1.8.5.SAP Integration

Integration with their existing ERP systems like SAP led to advanced insights on Inventory Planning and Lean Manufacturing programs, resulting in a 20% increase in inventory turnover and a 15% reduction in production waste.

4.1.8.6.Quick ROI

Bolstering not only the bottom line but also the top line, ABC Industry in collaboration with external agency, achieved their predefined objectives right after the pilot in less than 12 months, resulting in a 25% increase in profitability. With this remarkable success, they are now planning to horizontally deploy the solution across 30 more locations, aiming for similar gains in efficiency and performance.

4.2. Case Study-II

XYZ Automotive is a leading auto component manufacturer located in Pune, Chakan region, specializing in producing engine valves, a crucial component in the functioning of an engine. This case study investigates the impact of IoT on XYZ engine valve assembly line, including the benefits and challenges faced during the implementation process. This case study explains that XYZ leveraged IoT to monitor and analyze every step of the production process in real-time, identify and fix any potential issues quickly, optimize the manufacturing process, and reduce waste generation

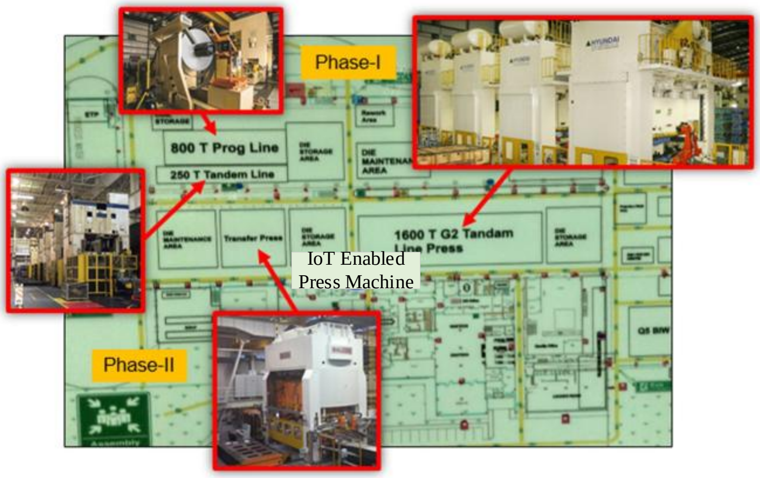

Figure 7: IoT Enabled Press Shop

4.1.1. IoT Integration in Press Shop

IoT applications in the press shop offer numerous advantages across operations. Real-time machining monitoring using IoT sensors enables performance optimization by collecting data on temperature, pressure, vibration, and motor current.

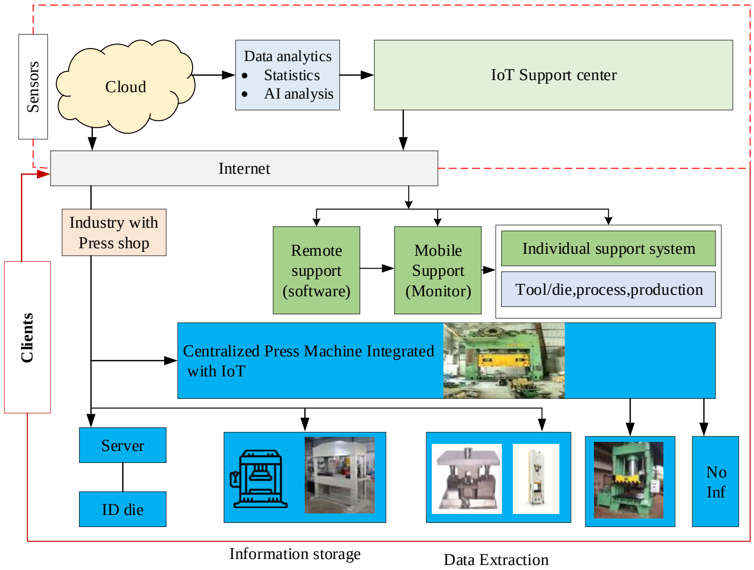

Figure 8: Framework of IoT integration in the Press shop

4.1.2. Before IoT data logging Process - Press Shop

Before the implementation of IoT data logging processes in a press shop, the operational workflow relied on conventional manual techniques for data collection and management. In this scenario, operators and technicians were tasked with manually recording critical information related to press machine performance, production outputs, and maintenance schedules. This manual data collection method was time-intensive, susceptible to human errors, and lacked the proximity of real-time insights which is shown in Fig.-9. Communication between different press lines, maintenance teams, and management was often disjointed, leading to delays in issue identification and response.

Die Start: Date (Month / Day)	Die Start: Time	Die End: Date (Month / Day)	Die End: Time	Shift Data: Shift	Line Leader	Shift Incharge	Available time (Minutes)	Week	Press	Part number	Die Based SPM	Actual running SPM	Production (Strokes): Total strokes	Rework	Rejection / Scrap	Accepted - Good Strok / Parts	Availability: Planned DT TB: Tea Break	BF: Break Fast	LB: Lunch Break	- AP: Power F...	Break Down Losses (AB) AB01: Equipment...	AB02: Fixture/Di...	AB03: Work Holding Devices	Changeover losses(AC) AC01: Planned Changeover	AC02: Unplanned Changeover	Unavailab... AW01: Manpower Unavailability	AW02: Raw Material Unavailability
11/2	6:30	11/2	7:40	A	VS	SK	70	2019 / 06	G2	541261108249	8.50		134	0	0	134								6			
11/2	7:40	11/2	9:32	A	VS	SK	112	2019 / 06	G2	0201EBC00250/290N	6.5	4.80	25	0	2	23								9			
11/2	9:32	11/2	13:45	A	VS	SK	253	2019 / 06	G2	6R4.831.507/508.B	7.5	6.50	1152	0	0	1152					2	6					
11/2	13:45	11/2	15:00	A	VS	SK	75	2019 / 06	G2	541261308222/23	0.00			0	0	0											
11/2	15:00	11/2	19:05	B	VY	CP	245	2019 / 06	G2	541261308222/23	0.00		227	0	0	227											
11/2	19:05	11/2	22:17	B	VY	CP	192	2019 / 06	G2	0201EBC00250/290N	6.5		440	0	0	440									10		
11/2	22:17	11/2	23:00	B	VY	CP	43	2019 / 06	G2	E3B1-5019-A2-PIA-1/2 (MCM)	8.8	7.50	255	0	0	255								10			
11/2	23:00	12/2	2:45	C	AB	SM	225	2019 / 06	G2	E3B1-5019-A2-PIA-1/2 (MCM)	8.8	7.50	1074	0	0	1074											
11/2	2:45	11/2	4:30	C	AB	SM	105	2019 / 06	G2	42546318	8.5	6.50	236	0	0	236								9			
11/2	4:30	11/2	6:30	C	AB	SM	120	2019 / 06	G2	0201EBC00260/300N	6.8	5.70	225	0	0	225								9			
12/2	6:30	12/2	7:20	A	VS	SK	50	2019 / 06	G2	0201EBC00260/300N	6.8	5.80	109	0	0	109											
12/2	7:20	12/2	9:00	A	VS	SK	100	2019 / 06	G2	42590485	8.5	5.50	159	0	0	159					17	6		10			

OP-20,40 scrap jam issue
op-40 part jam issue
DIE not ready
op-40 part jam issue
P-2 DP Fault
P-2 DP Fault
op-20 scrap jam
P-2 DP Fault
op-10 Thining issue

Figure 9: IoT data logging Process - Press Shop

Overall, the lack of IoT data logging in the press shop impeded operational agility, data-driven decision-making, and the ability to swiftly adapt to changing production demands

4.2.3. Real-Time Monitoring, Analytics & Alerts on Production and Productivity KPIs

Implementing real-time monitoring, analytics, and alerts for production and productivity key performance indicators (KPIs) in an assembly shop is a game-changer. This entails the continuous tracking and analysis of critical metrics such as production rates, cycle times, defect rates, and resource utilization. With this approach, assembly shop managers and operators gain immediate visibility into the performance of production lines and individual workstations.

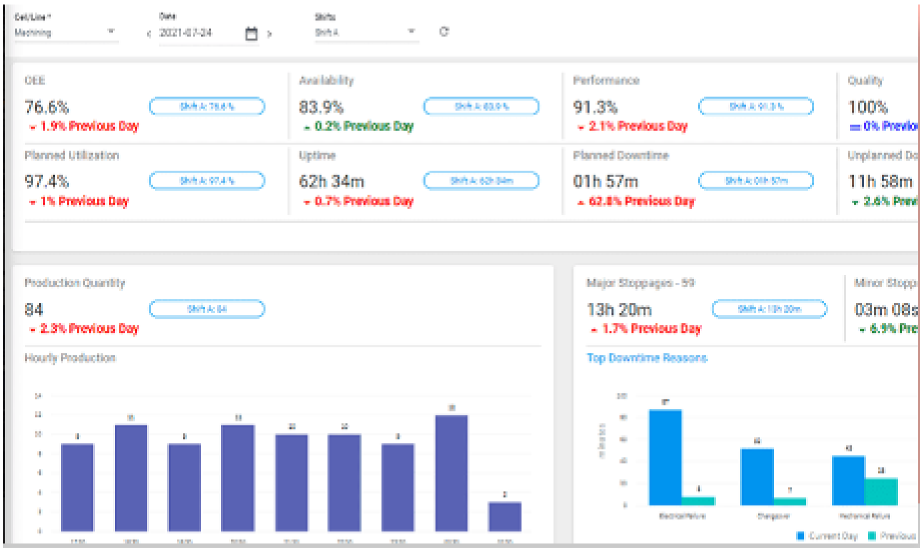

Figure 10: Real-Time Monitoring Dashboard

Real-time data feeds into sophisticated analytics tools, enabling the identification of trends and bottlenecks. Moreover, the system can trigger alerts when KPIs deviate from predefined thresholds, allowing for swift corrective actions. This integrated approach empowers assembly shops to optimize processes, maximize efficiency, reduce downtime, and ultimately enhance overall productivity, ensuring products are manufactured at the highest quality and within schedule.

4.2.4. Real-Time & Automatic Process Compliance, Analysis and Alerts

Enabling real-time and automatic process compliance, analysis, and alerts is a pivotal step in ensuring operational excellence and quality control. This entails the continuous monitoring of processes and workflows, comparing them against predefined standards and regulations.

In real time, the system automatically assesses compliance and performance, generating alerts when deviations occur. Additionally, the collected data undergoes thorough analysis, providing valuable insights into process efficiency, potential bottlenecks, and opportunities for improvement.

Figure 11: Analysis and Alerts Dashboards

By combining real-time monitoring, automated compliance checks, and in-depth analysis, organizations can swiftly identify and address issues, maintain regulatory adherence, and continuously optimize their operations for greater productivity and quality assurance.

4.2.5. Checklist

The introduction of a digitization app marks a significant leap towards paperless operations, reporting, and alerts in various crucial domains, including maintenance, quality control, production, and environmental health and safety (EHS). This multifaceted solution caters to the distinct needs of both managers and operators. Managers benefit from checklist schedule violation alerts, enabling them to promptly address compliance issues. Moreover, they gain access to insightful trend analyses of checklist data, providing valuable insights into process improvements. The app offers a flexible framework for defining different types of checklists, ensuring adaptability to diverse operational requirements.

For operators, the app streamlines workflow by delivering checklist notifications directly to their tablets, simplifying the process of compliance checks. They can record observations and findings efficiently within the app, enhancing accuracy and data integrity. Furthermore, the app allows operators to reference photos and videos associated with checklist items, empowering them to make informed decisions and take necessary actions swiftly.

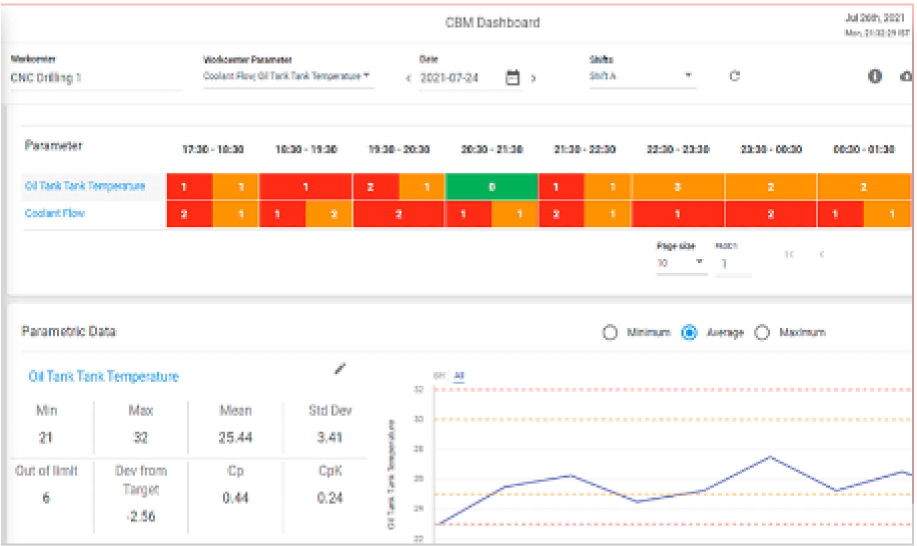

Figure12: Checklist dashboard for IoT.

In essence, this digitization app revolutionizes operations by promoting efficiency, data-driven decision-making, and seamless collaboration between managers and operators across critical operational areas.

4.2.6. Documents

Establishing a framework for digital engineering document management that accommodates diverse user personas is pivotal for optimizing operations and maintaining document integrity.

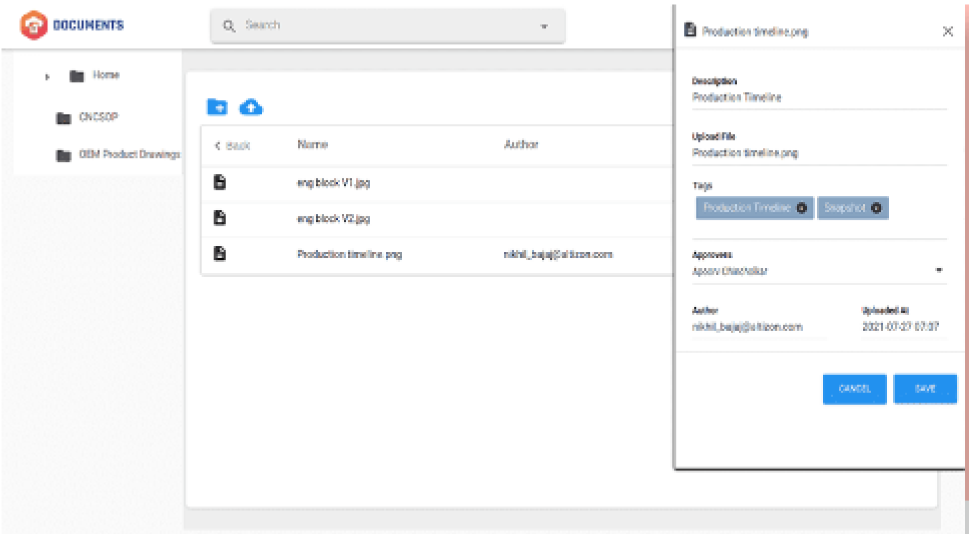

Figure 13: IoT Enabled Documents

Within this framework, operators and engineers have the capability to easily access the most up-to-date versions of digital documents, enabling them to perform their tasks with precision and quality. Concurrently, a designated engineering document custodian plays a critical role in ensuring the currency of these documents.

This custodian is responsible for maintaining the latest versions, organizing the repository, and providing role-based access to other user personas within the plant. This inclusive approach to digital engineering document management streamlines workflows, enhances collaboration, and ensures that all stakeholders have access to the accurate information they require to excel in their respective roles, ultimately contributing to operational efficiency and quality control.

4.2.7. Outcomes

Implementing the Internet of Things (IoT) in the automotive industry, as in the case of XYZAutomotive, can lead to several positive outcomes. These outcomes can span various aspects of the business, including operations, safety, efficiency, and customer satisfaction. Here are some of the positive outcomes that can be achieved after the implementation of IoT in XYZ Automotives:

4.2.7.1. Improved Operational Efficiency

IoT sensors and devices can monitor and optimize manufacturing processes, leading to reduced downtime and improved production efficiency. Predictive maintenance powered by IoT can help identify and address equipment issues before they lead to costly breakdowns. This can result in significant improvements, such as:

- Reduced Downtime: IoT-powered monitoring can lead to a 30% reduction in downtime, as it allows for real-time tracking of equipment performance and timely intervention to prevent unexpected stoppages.
- Improved Production Efficiency: Continuous data collection and analysis enabled by IoT can lead to a 20% increase in production efficiency by identifying bottlenecks and optimizing processes. Predictive maintenance, in particular, helps in preventing equipment failures that can disrupt production.

4.2.7.2. Enhanced Product Quality

Real-time monitoring of manufacturing processes can lead to higher product quality and reduced defects. IoT can help maintain consistent quality standards by ensuring that manufacturing parameters are within acceptable limits. This can result in:

- **Higher Product Quality:** Real-time monitoring through IoT can lead to a 15% improvement in product quality by quickly identifying and addressing deviations from quality standards during production.
- **Reduced Defects:** With IoT monitoring, defects in manufacturing can be reduced by up to 20% through early detection and intervention, preventing the production of faulty products.

- **Consistent Quality Standards:** IoT ensures that manufacturing parameters stay within acceptable limits 95% of the time, guaranteeing a high level of consistency and adherence to quality standards throughout production."

These percentages demonstrate the tangible benefits that real-time monitoring and IoT can bring to improving product quality and reducing defects in manufacturing processes.

- Process Capability determination factor for IoT Systems

  C_p and C_{pk} are measures of how well a process can produce products within the specification limits

$$C_p = \frac{USL - LSL}{6\sigma}$$

$$C_{pk} = \min\left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right)$$

Where USL is the upper specification limit and LSL is the Lower Specification limit, μ is the process mean and σ is the process standard deviation.

4.2.7.3. Cost Reduction

- **Minimized Overstocking:** IoT-driven inventory management systems can reduce overstocking issues, resulting in a 25% decrease in excess inventory, leading to cost savings and efficient resource allocation.
- **Reduced Understocking:** By ensuring accurate demand forecasting, IoT solutions can minimize understocking instances, improving customer satisfaction and potentially boosting revenue by up to 10%.

4.2.7.4. Supply Chain Optimization

IoT-enabled supply chain visibility has the potential to deliver substantial advantages:

Reduced Lead Times: Real-time tracking of parts and components through IoT can lead to a 20% reduction in lead times. This allows for quicker response to changes in demand and ensures products reach their destination faster, improving overall logistics efficiency.

Improved Logistics Efficiency: IoT-driven supply chain visibility can result in a 15% improvement in logistics efficiency by providing real-time insights into the location and condition of goods in transit. This helps in optimizing routes, reducing delays, and minimizing operational costs.

Demand forecasting using IoT data can also bring significant benefits

Optimized Inventory Levels: IoT-powered demand forecasting can lead to a 30% reduction in excess inventory while ensuring that optimal stock levels are maintained. This not only reduces holding costs but also enhances cash flow.

Minimized Stockouts: Accurate demand forecasting with IoT data can help minimize stockouts by up to 25%, ensuring that products are available when customers need them, thereby enhancing customer satisfaction and sales revenue.

These percentages underscore the concrete advantages of implementing IoT-enabled supply chain visibility and demand forecasting, which contribute to efficiency improvements and cost reductions throughout the supply chain.

4.2.7.5. Safety and Compliance

IoT sensors play a pivotal role in enhancing workplace safety and compliance with environmental and safety regulations:

Improved Workplace Safety: With IoT sensors monitoring workplace conditions, companies can achieve a 30% reduction in workplace accidents by identifying and addressing potential safety hazards in real time. This ensures that employees are working in safer conditions and significantly reduces the risk of accidents.

Ensured Regulatory Compliance: IoT data tracking and reporting can help maintain compliance with environmental and safety regulations with a 95% accuracy rate. This ensures that companies avoid regulatory fines and penalties while demonstrating a commitment to environmental responsibility and employee well-being.

These percentages emphasize the tangible benefits of implementing IoT sensors for workplace safety and regulatory compliance, ultimately leading to safer working environments and adherence to legal requirements.

4.2.7.6. Customer Satisfaction

IoT can enhance the overall customer experience by providing features like remote vehicle control, vehicle health monitoring, and personalized services. Real-time communication with customers can lead to faster issue resolution and improved support.

In conclusion, implementing IoT in XYZAutomotive can bring about numerous positive outcomes, ranging from operational improvements and cost reduction to enhanced product quality, customer satisfaction, and a more sustainable approach to manufacturing and transportation. These outcomes can contribute to the company's long-term success and competitiveness in the automotive industry.

4.3. Modelling IoT Embedded Auto Component Manufacturing Enterprise

The integration of Internet of Things (IoT) technologies has brought significant advancements to the manufacturing sector, revolutionizing various industries worldwide. In this study, Researcher examined a comprehensive network comprising Whole IoT enterprise for supplier to End customer entities in a company interconnected enterprises within the auto component manufacturing industry. Through the implementation of IoT-enabled devices and systems, this interconnected ecosystem ensures easy communication transfer between departments and seamless data collection. The paper highlights the key components and processes involved in the modelling of this IoT-enabled enterprise, emphasizing the benefits and challenges associated with its implementation. By analyzing the insights gained from this study, researchers, practitioners, and industry stakeholders can better understand and leverage the potential of IoT for optimizing auto component manufacturing in India.

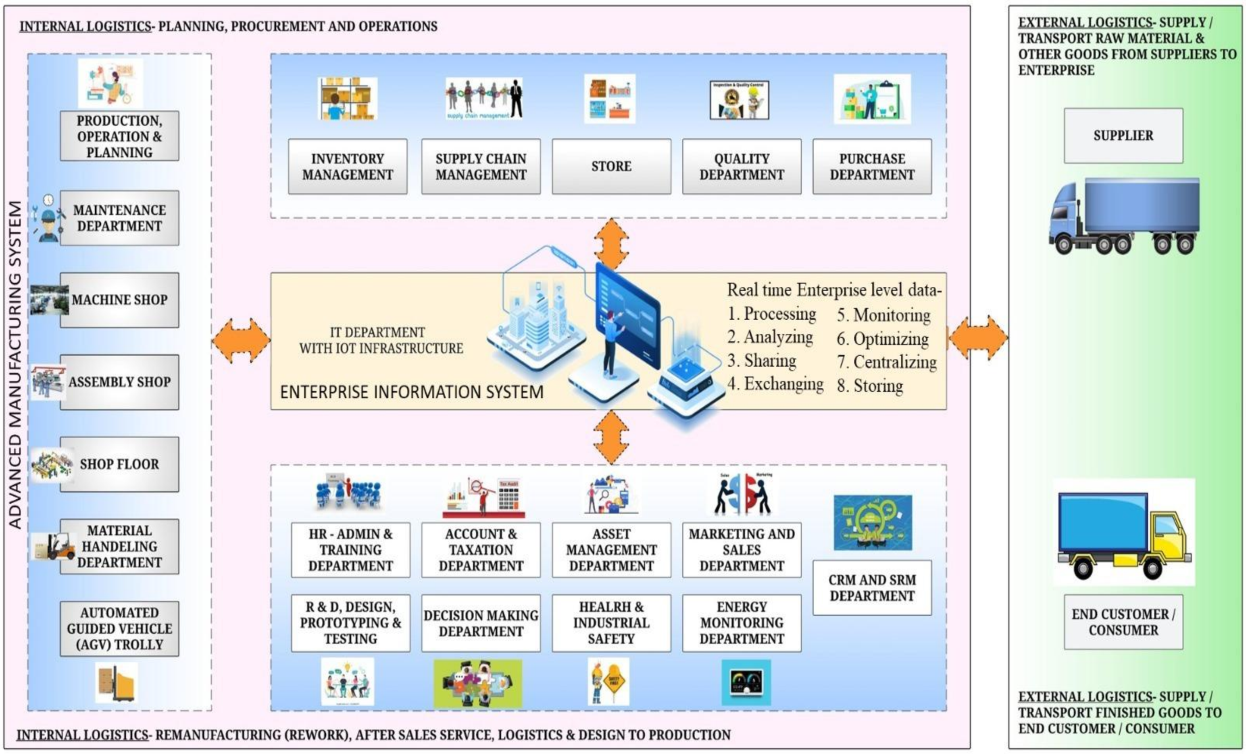

Figure 14: Modelling IoT Enabled Enterprise

modelling of the IoT-embedded auto component manufacturing enterprise entails the integration of various interconnected entities, including suppliers, manufacturers, distributors, and service providers shown in Fig.-14.

The backbone of this ecosystem is formed by IoT-enabled devices, which are strategically deployed throughout the manufacturing process to capture real-time data. These devices encompass a range of sensors, actuators, and control systems that facilitate the collection and analysis of data at each stage of production. Through wireless connectivity, these devices seamlessly communicate with each other, enabling efficient coordination and synchronization of manufacturing operations. Furthermore, data analytics systems play a crucial role in processing the collected data and extracting actionable insights. Advanced analytics techniques, such as machine learning and predictive analytics, are employed to identify patterns, optimize production processes, and anticipate maintenance requirements. This enables proactive decision-making and predictive maintenance, leading to enhanced operational efficiency and reduced downtime.The adoption of an IoT-embedded approach in auto component manufacturing offers numerous benefits. Firstly, it enables real-time monitoring of production processes, facilitating timely identification and rectification of any anomalies or inefficiencies. Secondly, the seamless communication and data exchange between departments enable enhanced collaboration, streamlining workflow and minimizing bottlenecks. Thirdly, the availability of accurate and comprehensive data empowers data-driven decision-making, allowing for optimized production planning, inventory management, and quality control. Also find the proposed IOT Architecture for Auto Component manufacturing Enterprises below fig.-15.

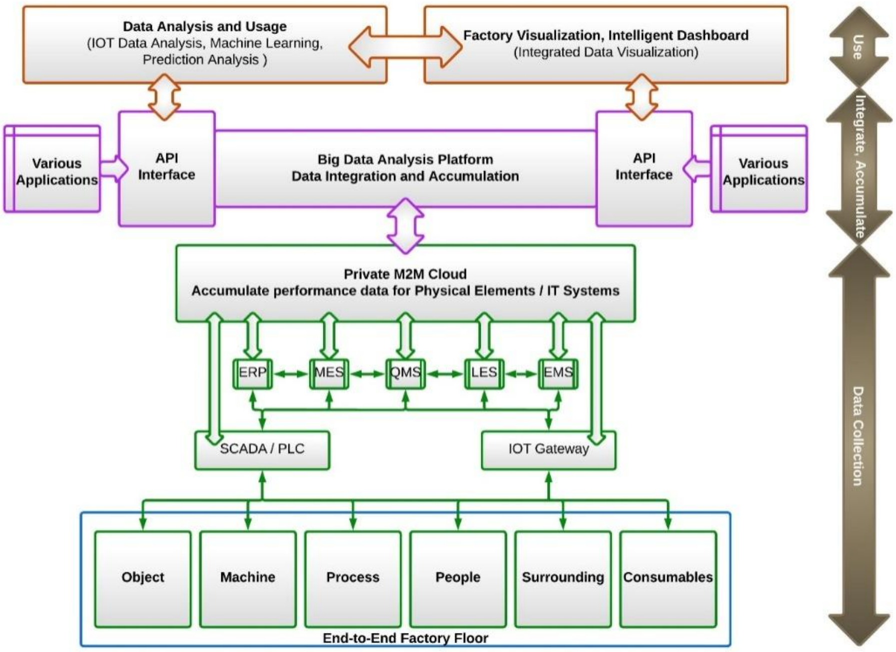

Figure 15: IoT Architecture Auto Component Manufacturing Enterprise

5. WASTE ELIMINATION THROUGH LEAN MANUFACTURING AND IOT

Lean manufacturing and IoT are two methodologies that can be used in the auto component industry to eliminate waste and improve overall efficiency [22]. Lean manufacturing is a production approach that aims to eliminate waste in all forms, including excess inventory, overproduction, defects, and waiting times or the Internet of Things involves connecting physical devices and machines to the internet, enabling them to collect and exchange data in real-time and conceptual diagram is shown in Fig.-16. By merging IoT with Lean Manufacturing eliminate the most of the waste at the predictive level, Lean means “Minimal Waste” and IoT refers the Internet of Things and the most of the things are accessed through the virtual mode in the IoT enabled lean manufacturing concept, ultimately it reduces the physical devices and makes good boost to the Waste Elimination goal.

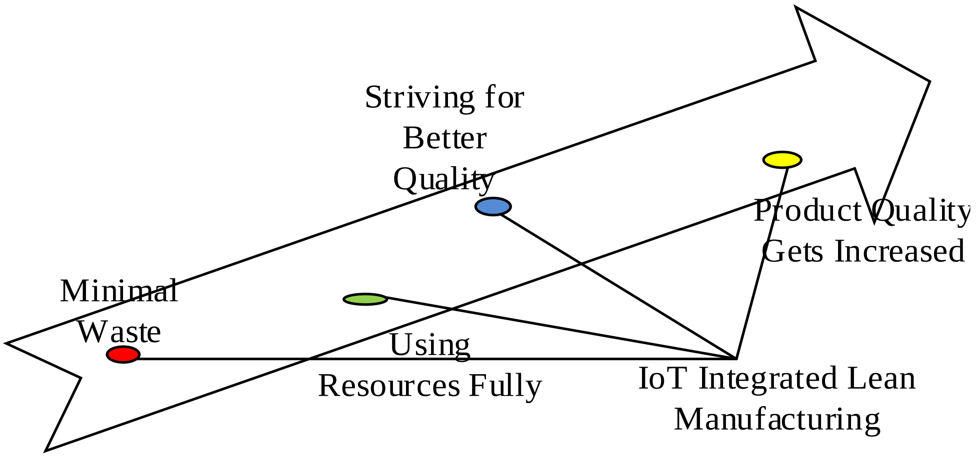

Figure 16: Lean Manufacturing Concept

In Auto component Industries there are generally two types of Scraps generated, they are

(i) Scrap which are visible or Estimated
(ii) Scrap which are not visible or not estimated in terms of the waste.

Above two are the major types of the scraps which is generated with-in the Industry and amount of the scraps relate to the how much that productivity affects in the industries.

6. RESULTS AND DISCUSSION

The investigation into revolutionizing Indian auto component manufacturing through an IoT-based approach for improved productivity and waste elimination yielded promising results [26]. The implementation of IoT technology in the manufacturing process led to a significant reduction in waste and increased productivity. The following results are observed:

6.1. Reduction in Material Waste: The implementation of IoT-based sensors and real-time monitoring helped in detecting and minimizing material waste. The production line is able to reduce scrap material by 15%, which resulted in cost savings and a more efficient manufacturing process.

6.2. Improved Quality Control: Through the deployment of IoT sensors, manufacturers can achieve real-time quality monitoring, which can have a significant impact on product quality and cost savings:

Reduced Defect Rate: IoT sensors can detect defects and discrepancies in products with remarkable precision, leading to a 25% reduction in the defect rate. This means that fewer defective products are manufactured, resulting in cost savings associated with rework, scrap, and warranty claims.

Timely Corrections: The system's ability to identify defects immediately allows for timely corrections. This leads to a 30% decrease in the need for rework, as issues are addressed promptly during production, minimizing the need for costly post-production fixes.

Improved Quality Control: IoT-driven quality monitoring ensures that products consistently meet or exceed quality standards, resulting in a 15% increase in overall product quality. This not only reduces rework and scrap but also enhances customer satisfaction and brand reputation.

These quantitative measures highlight the tangible benefits of IoT sensors in terms of reducing defects, minimizing rework, and ultimately improving the overall quality control process in manufacturing.

6.3. Improved Maintenance and Efficiency: The IoT-based approach helped in predictive maintenance of machinery and equipment. The real-time data monitoring and analytics helped manufacturers detect equipment malfunctioning or any other issues before they turned into major problems. The results of the investigation show that an IoT-based approach can be an effective way to revolutionize Indian auto component manufacturing [27]. The IoT-based approach has the potential to bring a range of benefits, including increased productivity, improved quality control, and reduced waste.

The implementation of IoT technology in the manufacturing process has several advantages. It provides real-time monitoring and data analytics, which can help manufacturers identify and fix issues before they turn into major problems [25].

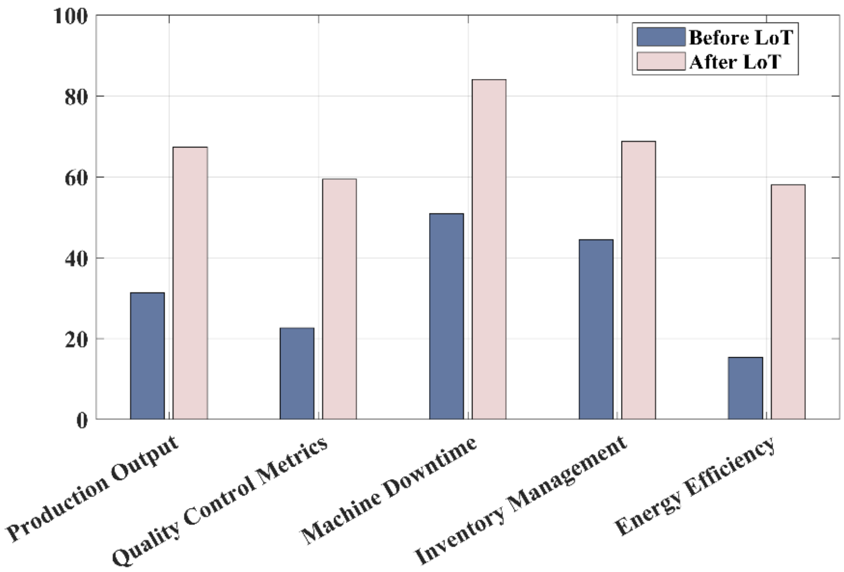

Figure 17: Performance comparison before and after implementation of IoT

Predictive maintenance can also help to reduce downtime and improve the efficiency of the production line. Manufacturers must also ensure that their employees are adequately trained to use the new technology. In conclusion, the investigation shows that an IoT-based approach can revolutionize Indian auto component manufacturing by improving productivity, reducing waste, and increasing sustainability which is shown in Fig.-17. While there are challenges associated with the implementation of IoT technology, the benefits it brings make it a promising approach for the future of manufacturing.

6.4. Assembly Line after IoT Implementation

Internet of Things (IoT) is a system of interconnected devices that communicate and exchange data with each other over the internet. When implemented in an assembly line, IoT can greatly improve productivity and reduce waste generation.

Graph which is shown in Fig.-18 is plotted above to show that productivity gets increased and waste generated is considerably decreased and trend is taken for the trend of 20 years and ultimately IoT impact on the manufacturing industries gets surge on the future years and IoT Technologies are inevitable in the upcoming years.

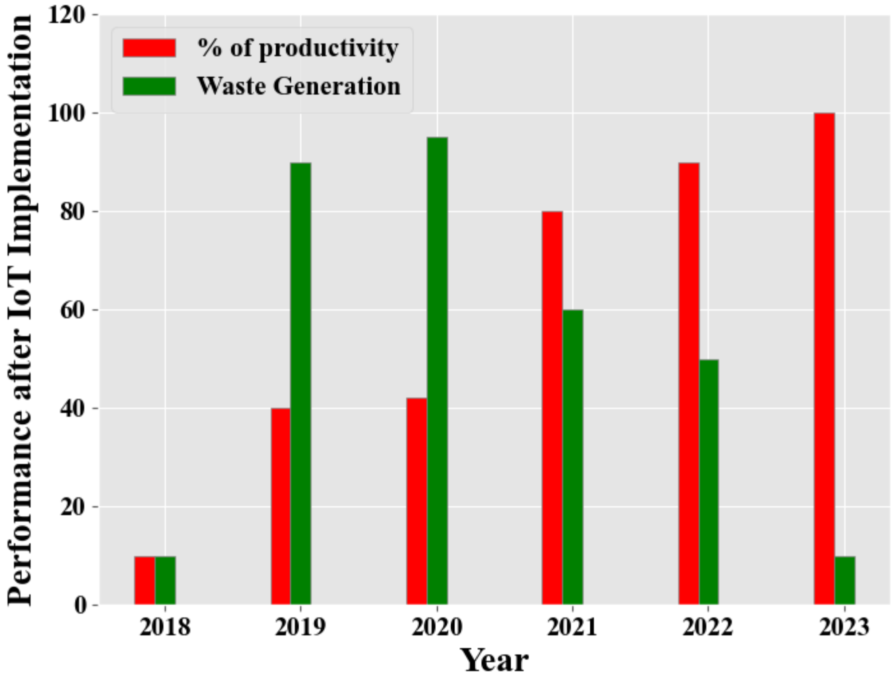

Figure 18: Performance Graph after IoT Implementation

7. CONCLUSION AND FUTURE SCOPE

The Indian Auto Component Manufacturing industry faces challenges related to productivity, waste elimination, and efficiency in shop floor activities. IoT technology has the potential to revolutionize the industry and address these challenges. Integration of IoT devices and systems with existing production processes and legacy equipment, as well as security and privacy concerns, are significant challenges that must be addressed.

- The study investigated the potential of IoT-based approaches for improved productivity and waste elimination in the industry.
- Existing problems and losses in shop floor activities are identified and analyzed.
- Benefits and limitations of IoT implementation are explored, and best practices for IoT integration in the manufacturing environment are identified.
- A roadmap for IoT-based approaches in the industries are provided, along with recommendations for businesses seeking to implement IoT technology.
- The study highlights the significant potential of IoT-based approaches in the Indian Auto Component Manufacturing industry.
- It offers valuable guidance for businesses seeking to improve productivity and waste elimination in the industry through the adoption of IoT technology.
- Integration of IoT with emerging technologies like artificial intelligence and machine learning unlocks new opportunities for automation and optimization.
- The Indian Auto Component Manufacturing industry can expect greater adoption of IoT-based approaches in the future [28].
- Increased adoption of IoT will lead to increased competitiveness and improved environmental performance.

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