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Key factors driving the potential future developments in automated manufacturing at Hindustan aeronautics ltd (HAL)

Abstract

This research aims to explore the key factors driving the application of Big Data and IoT/AI in potential future developments of automated manufacturing at Hindustan Aeronautics Ltd (HAL). By investigating the current state of automated manufacturing, the study will identify the benefits and challenges associated with integrating Big Data, IoT, and AI technologies. The research questions will focus on understanding the factors influencing the adoption of these technologies, their impact on manufacturing processes, and the potential benefits they offer to HAL. The research objectives include analysing the current landscape of automated manufacturing, identifying key factors driving the application of Big Data and IoT/AI, assessing the benefits and challenges of implementing these technologies, and providing recommendations for HAL's future developments in automated manufacturing.

Keywords: emerging technologies, automated manufacturing, aeronautics, Indian aviation, process flow, big data, IOT, AI, automated manufacturing, Hindustan aeronautics ltd (HAL), application, key factors, benefits, challenges, integration, technology adoption

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Introduction

Automated manufacturing is rapidly evolving, driven by advancements in technology such as Big Data, the Internet of Things (IoT), and Artificial Intelligence (AI). Hindustan Aeronautics Ltd (HAL), a leading aerospace and defence company, recognizes the potential of these technologies in shaping the future of manufacturing. This research aims to identify the key factors driving the application of Big Data and IoT/AI in potential future developments of automated manufacturing at HAL. By understanding these factors, HAL can leverage the benefits offered by these technologies and make informed decisions for their manufacturing processes.[1]

Background

The manufacturing industry is undergoing a significant transformation with the advent of Big Data, IoT, and AI. Big Data refers to the vast amount of data generated from various sources, including sensors, machines, and processes. IoT enables the connection and communication between physical devices, collecting real-time data and facilitating automation. AI, on the other hand, utilizes advanced algorithms and machine learning to analyse data, make predictions, and automate decision-making.[2]

HAL, as a prominent player in the aerospace and defence sector, recognizes the importance of embracing digital technologies to improve their manufacturing processes. The integration of Big Data, IoT, and AI has the potential to enhance efficiency, productivity, quality control, and predictive maintenance in automated manufacturing. By leveraging these technologies, HAL can optimize their operations, reduce costs, and gain a competitive edge in the industry.[3]

However, the adoption of these technologies in automated manufacturing is not without challenges. Factors such as data security, infrastructure requirements, skill gaps, and the need for effective data management strategies pose significant challenges for HAL. Therefore, it becomes crucial to identify the key factors that drive the application of Big Data and IoT/AI in potential future developments of automated manufacturing at HAL. Understanding these factors will enable HAL to navigate the complexities and make informed decisions regarding technology adoption and implementation.[4]

This research aims to analyse the current state of automated manufacturing at HAL, investigate the factors influencing the adoption of Big Data, IoT, and AI technologies, and assess the benefits and challenges associated with their implementation. By addressing these key factors, the study will provide valuable insights and recommendations for HAL's future developments in automated manufacturing, ultimately contributing to their success in the ever-evolving aerospace and defence industry.[5]

Research scope

The research will primarily focus on the application of Big Data and IoT/AI in potential future developments of automated manufacturing at Hindustan Aeronautics Ltd (HAL). It will analyse the current state of automated manufacturing, investigate the factors influencing the adoption of Big Data, IoT, and AI technologies, and assess the benefits and challenges associated with their implementation. The research will provide insights and recommendations specific to HAL's context.

Research questions

1. What are the key factors driving the application of Big Data and IoT/AI in potential future developments of automated manufacturing at HAL?
2. What are the benefits and challenges associated with integrating Big Data, IoT, and AI technologies in the manufacturing processes at HAL?
3. What are the potential future developments and improvements that HAL can achieve by leveraging Big Data and IoT/AI in their automated manufacturing?

Research objectives

1) Identify the key factors driving the application of Big Data and IoT/AI in potential future developments of automated manufacturing at HAL.

2) Assess the benefits and challenges associated with integrating Big Data, IoT, and AI technologies in the manufacturing processes at HAL.

3) Explore potential future developments and improvements that HAL can achieve by leveraging Big Data and IoT/AI in their automated manufacturing processes.

Review of literature

The application of Big Data, IoT (Internet of Things), and AI (Artificial Intelligence) in automated manufacturing at Hindustan Aeronautics Ltd (HAL) can greatly impact its future developments. Several key factors drive the adoption of these technologies. Big Data analytics enable HAL to collect, store, and analyse vast amounts of data generated from various sources within the manufacturing process. This data can provide valuable insights into operational efficiency, quality control, and predictive maintenance. By leveraging this information, HAL can make informed decisions to optimize production processes, reduce costs, and improve overall performance. IoT and AI technologies enable the interconnectivity of devices, sensors, and machines on the shop floor.[6] This connectivity allows real-time monitoring of manufacturing operations, facilitating proactive maintenance, reducing downtime, and improving productivity. HAL can use AI algorithms to identify patterns, anomalies, and bottlenecks in the production line, thereby streamlining operations and enhancing efficiency. Big Data analytics combined with AI algorithms can analyze historical data to identify patterns and predict potential failures or quality issues. By continuously monitoring the performance of manufacturing equipment and components, HAL can proactively schedule maintenance activities, reducing unplanned downtime and improving overall equipment effectiveness. This approach can ensure that the manufactured products meet stringent quality standards.[7] Big Data analytics can help HAL analyze the entire supply chain, from raw material sourcing to distribution. By integrating data from suppliers, logistics partners, and internal systems, HAL can gain insights into inventory management, demand forecasting, and logistics optimization. This data-driven approach can minimize supply chain disruptions, reduce costs, and improve customer satisfaction. The combination of IoT and AI technologies enables HAL to automate various manufacturing processes, such as assembly, testing, and inspection. By leveraging machine learning algorithms, the manufacturing systems can adapt and optimize themselves based on real-time data. This intelligent automation can lead to increased productivity, reduced errors, and improved product quality. In summary, the key factors driving the application of Big Data, IoT, and AI in automated manufacturing at HAL include data-driven decision-making, enhanced operational efficiency, quality control, predictive maintenance, supply chain optimization, and intelligent automation. These technologies have the potential to revolutionize manufacturing processes, enabling HAL to achieve higher productivity, improved quality, and cost savings in the future.[8]

The automated manufacturing of aircraft can greatly benefit from the integration of Big Data, IoT (Internet of Things), AI (Artificial Intelligence), and ML (Machine Learning). Big Data analytics can collect, and process vast amounts of data generated across the manufacturing process. This includes data from sensors, machines, quality control systems, and various other sources. By analysing this data, manufacturers can gain insights into production performance, identify bottlenecks, optimize workflows, and make data-driven decisions to improve efficiency and quality.[9]

IoT devices and sensors can be deployed across the manufacturing floor, on machines, and in components, creating a connected ecosystem. These devices can collect real-time data and transmit it to a central system for analysis. This connectivity enables manufacturers to monitor and control manufacturing processes remotely, ensuring consistency, reducing errors, and enabling predictive maintenance.[10] By leveraging AI and ML algorithms, manufacturers can predict and prevent equipment failures or performance issues. By analyzing historical data and real-time sensor data, AI can identify patterns and anomalies that indicate potential breakdowns. This allows for proactive maintenance scheduling, reducing downtime, and optimizing the lifespan of machinery. Big Data analytics combined with AI and ML algorithms can improve quality control processes. By analyzing data from various sources, such as sensors, inspection systems, and testing results, manufacturers can identify patterns and indicators of potential defects. AI-powered visual inspection systems can detect even the slightest defects in components or assemblies, ensuring high-quality aircraft. AI and ML algorithms can analyse vast amounts of data to optimize manufacturing processes.[11] By identifying patterns and correlations, these technologies can optimize production workflows, reduce waste, and improve efficiency. Additionally, AI can automate repetitive or complex tasks, such as assembly or testing, increasing productivity and freeing up human resources for more strategic roles. Big Data and AI can optimize the aircraft manufacturing supply chain. By analysing data from suppliers, logistics partners, and internal systems, manufacturers can improve inventory management, demand forecasting, and logistics planning. This can minimize delays, reduce costs, and ensure timely delivery of components and materials. In summary, the integration of Big Data, IoT, AI, and ML in aircraft manufacturing supports data-driven decision-making, predictive maintenance, quality control, process optimization, automation, and supply chain management. These technologies enable manufacturers to improve efficiency, reduce costs, enhance quality, and ultimately deliver safer and more reliable aircraft.[12]

Big Data, IoT, AI, and ML can play significant roles in designing, structuring, flight parameters checking, testing, and sleuth enhancement of fighter aircraft engines, bodies, materials, and systems. Big Data analytics can analyse vast amounts of historical design and performance data to identify patterns and optimize the design process. AI and ML algorithms can assist in generating innovative design solutions by simulating and evaluating multiple possibilities. These technologies can also help in structuring the aircraft by analyzing and optimizing the arrangement of components, ensuring optimal weight distribution, aerodynamics, and structural integrity.[13]

IoT devices and sensors can be integrated into aircraft systems to collect real-time data during flight. This data can include parameters such as engine performance, fuel consumption, altitude, speed, temperature, and more. Big Data analytics can process this data in real-time, comparing it with predefined parameters and safety thresholds. Any deviations or anomalies can be flagged, allowing for immediate action or further investigation.[14]

Data analytics can analyse extensive historical and real-time data from engine tests, wind tunnel experiments, and material testing to identify patterns and optimize performance. AI and ML algorithms can assist in predicting and simulating the behaviour of engines, bodies, and materials under various conditions. This helps engineers in identifying potential issues, improving efficiency, and enhancing

safety. Big Data analytics can analyse vast amounts of data from various sources, including sensors, cameras, radar, and communication systems, to enhance the sleuth capabilities of fighter aircraft. AI and ML algorithms can process this data to identify and track potential threats, analyse patterns, and make real-time decisions. This can assist pilots and defence personnel in detecting and responding to threats effectively.[15]

Moreover, the integration of these technologies enables other additional capabilities.

- Predictive maintenance: AI and ML algorithms can analyze data from aircraft sensors, maintenance records, and historical data to predict potential engine or system failures. This allows for proactive maintenance, reducing downtime and ensuring optimal performance.[16]

- Material selection and optimization: Big Data analytics can assess material performance data from various sources to identify suitable materials for fighter aircraft. AI and ML algorithms can optimize material selection, considering factors such as strength, weight, heat resistance, and durability.[17]

- Simulation and virtual testing: AI and ML algorithms can simulate and predict the behaviour of fighter aircraft engines, bodies, and materials in various scenarios. This allows for virtual testing, reducing the need for physical prototypes and accelerating the design and testing process.[18]

In summary, the integration of Big Data, IoT, AI, and ML technologies can revolutionize the design, testing, performance monitoring, and sleuth enhancement of fighter aircraft engines, bodies, materials, and systems. These technologies enhance safety, improve efficiency, optimize performance, and contribute to the overall success of modern fighter aircraft.[19]

Automated fighter aircraft manufacturing can be used effectively by involving technology in the operations.

a. Design and Simulation: The process begins with designing the aircraft using computer-aided design (CAD) software. This step involves creating a detailed 3D model of the aircraft, including its components and systems. Simulations using virtual reality (VR) or augmented reality (AR) can be performed to validate the design and ensure manufacturability.[20]

b. Robotic Assembly: Automated robotic systems are utilized for the assembly of fighter aircraft components. The robots can be programmed to perform tasks such as welding, riveting, drilling, and fastening with precision and repeatability. These robots can work in collaboration with human operators to optimize efficiency and safety.[21]

c. Additive Manufacturing: Additive manufacturing, also known as 3D printing, can be employed to fabricate specific components of the fighter aircraft. This technology allows producing complex geometries and reduces the need for multiple parts, leading to weight reduction and improved performance.[22]

d. Quality Control: Automated inspection systems, including machine vision and non-destructive testing techniques, can be utilized for quality control during the manufacturing process. These systems can detect defects, measure tolerances, and ensure that the components are manufactured to the required specifications.[23]

e. Data Analytics: Data generated during the manufacturing process, such as sensor readings and machine parameters, can be collected and analysed using Big Data analytics. This analysis helps in identifying trends, optimizing production processes, and ensuring quality control.[24]

f. Supply Chain Management: Automation can be extended to the management of the supply chain, including inventory management, procurement, and logistics. This ensures a streamlined and efficient flow of materials and components to support the manufacturing process.[25]

g. Effective communication and collaboration between different stakeholders, including design teams, manufacturing engineers, and production operators, are crucial for the success of automated manufacturing. Digital platforms and real-time communication tools can facilitate seamless information exchange and coordination.[26]

h. Continuous improvement methodologies, such as Lean Six Sigma, can be implemented to identify bottlenecks, optimize processes, and eliminate waste in the automated manufacturing workflow. Regular monitoring, analysis, and feedback loops help in identifying areas for improvement and implementing corrective actions.[27]

i. Adequate training and skill development programs should be provided to the workforce to adapt to the changing manufacturing environment. This includes training on operating and maintaining automated systems, programming robots, and utilizing data analytics tools.[28]

By following these steps, automated fighter aircraft manufacturing can be effectively implemented, resulting in increased productivity, improved quality, reduced costs, and faster production cycles. It also allows for greater flexibility in customization and adaptation to evolving design requirements.[29]

The most appropriate theory applicable to this research study is "Human-Machine Interaction Theory". The theory explores the relationship between humans and machines in the manufacturing environment. It focuses on designing user-friendly interfaces, considering ergonomics for operators working alongside automated systems, and ensuring effective collaboration between humans and machines. Understanding this theory is crucial for creating a harmonious and productive work environment.[30]

Hypotheses formulated

H1: There is significant influence of the Technology factors on the Successful automated manufacturing at Hindustan Aeronautics Ltd (HAL)

H2: There is significant influence of the Environment factors on the Successful automated manufacturing at Hindustan Aeronautics Ltd (HAL)

H3: There is significant influence of the Manufacturing Process factors on the Successful automated manufacturing at Hindustan Aeronautics Ltd (HAL)

H4: There is significant influence of the Human factors on the Successful automated manufacturing at Hindustan Aeronautics Ltd (HAL)

Methodology

The qualitative methodology seems to be most appropriate for this topic as the experts can throw light on the various factors which can drive the success of the HAL automated manufacturing of fighter aircraft. The other stakeholders cannot have a holistic view of the whole topic factors so will not be suitable for this topic (Figure 1).

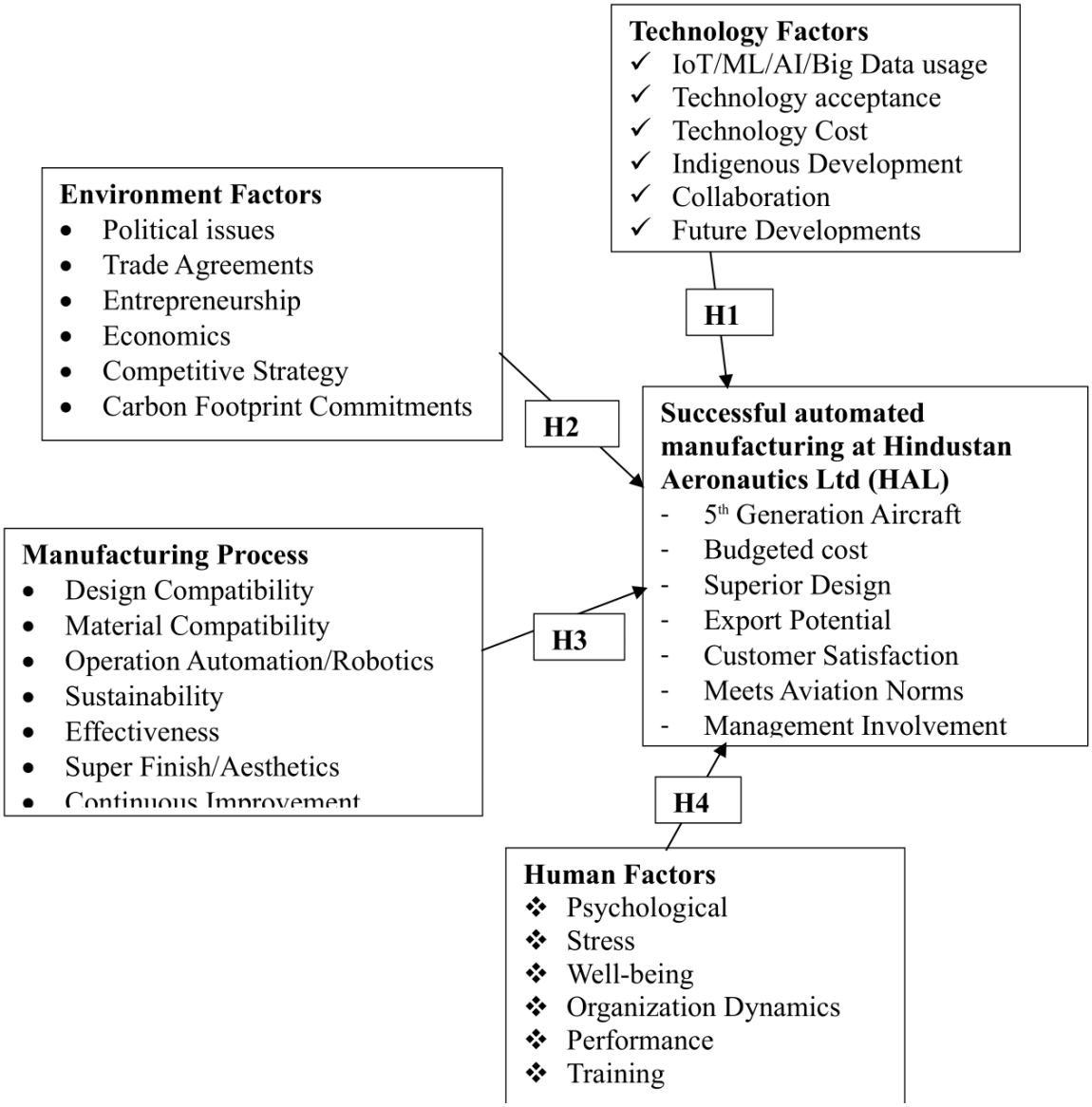

Figure 1 Human-machine interaction theory using technology- conceptual model.

Findings and discussions

The Interviews with the experts (20) were conducted, recorded and transcript, using thematic analysis and tabulated the results below using Zoom and MS teams (Table 1).

Hindustan Aeronautics Ltd (HAL) can improve on future improved fighter aircraft to meet customer expectations. HAL can focus on integrating advanced technologies into their fighter aircraft to meet customer expectations. This can include incorporating state-of-the-art avionics systems, advanced radar and sensor capabilities, improved stealth features, and enhanced communication systems. By adopting cutting-edge technologies, HAL can deliver fighter aircraft that meet the evolving needs of customers. HAL can offer customization options to meet specific customer requirements. This can involve providing modular design features that allow for easy integration of different weapons systems, sensor packages, and avionics configurations.[46] The ability to tailor the aircraft to individual customer's needs will enhance customer satisfaction and increase the value proposition of HAL's fighter aircraft. HAL can invest in research and development to improve the performance and capabilities of their fighter aircraft. This can include increasing speed, range, maneuverability, and payload capacity. By continually enhancing the performance of their aircraft, HAL can meet customer expectations for superior performance in combat scenarios. HAL can focus on improving the reliability and maintainability of their fighter aircraft. This can involve implementing advanced diagnostic and predictive maintenance systems, reducing the time required for maintenance and repairs, and ensuring high availability rates.[47] By delivering aircraft that are reliable and easy to maintain, HAL can minimize downtime and meet customer expectations for operational readiness. HAL can provide comprehensive training and support packages to their customers. This can include pilot training programs, maintenance training, and ongoing technical support. By ensuring that customers are well-trained and supported in operating and maintaining the aircraft, HAL can enhance customer satisfaction and build long-term relationships.

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HAL can navigate the challenges associated with conflicts by adhering to international regulations and export control policies. It is essential for HAL to maintain transparency and comply with relevant legal frameworks when engaging with conflict countries. HAL can also actively engage in diplomatic efforts to ensure responsible and ethical use of their fighter aircraft in conflict situations. By continuously improving on these aspects, HAL can meet customer expectations and contribute to addressing conflicts by providing advanced and reliable fighter aircraft that align with international norms and regulations.[48]

Table 1 Thematic analysis of the Interviews with the experts

Interviewee Serial no, (Experience in years), Location Designation,	Main comments on automated manufacturing at Hindustan Aeronautics Ltd (HAL) (Other Interviewees in agreement to the comments)
1., (15), Vice President Logistics Onam	- IoT can enable HAL to connect various manufacturing devices, sensors, and systems, allowing seamless communication and data sharing
	- Connectivity can improve efficiency, predictive maintenance, and real-time monitoring of production processes.
	- AI-powered algorithms can optimize production schedules, detect anomalies, and improve quality control.
	- The use of big data analytics can provide valuable insights into manufacturing operations, quality control, and supply chain management.
	- The successful adoption of automated manufacturing relies on the acceptance and integration of these new technologies by HAL's workforce (Interviewee 4, 6, 9, 12)-31
2., (23), CEO, Aviation Company, India	- AI can enhance automated manufacturing at HAL by enabling machines to learn, adapt, and make decisions independently.
	- Analyzing large volumes of data can help HAL make data-driven decisions, improve production processes, and identify areas for optimization.
	- Proper training, education, and change management strategies play a vital role in ensuring the smooth transition to automated manufacturing.
	- HAL needs to carefully evaluate the return on investment, considering factors such as equipment, software, infrastructure, and ongoing maintenance costs.
	- HAL's focus on indigenous development of technologies can lead to self-reliance and customization of solutions specific to their requirements. (Interviewee 1, 4, 7, 8, 13).[32]
3., (18), Vice President Aircraft Operations, Dubai	- The cost of implementing and maintaining the required technologies can impact the success of automated manufacturing.
	- This approach can result in better control, reduced dependency on external vendors, and enhanced competitiveness.
	- Collaborative efforts can accelerate technology adoption, innovation, and overall success in automated manufacturing.
	- Continuous investment in research and development, exploring emerging technologies, and adapting to market demands will ensure HAL remains at the forefront of manufacturing excellence.
	- Political stability, government regulations, and policies can impact HAL's automated manufacturing initiatives (Interviewee 4, 6, 8, 11).[33]
4., (15), General Manager, IT Department , Government Aviation Supplier Company	- Staying abreast of technological advancements and industry trends is crucial for HAL's long-term success in automated manufacturing.
	- Collaborating with technology partners, research institutes, and other industry players can bring valuable expertise, resources, and novel solutions to HAL.
	- Favorable policies, such as incentives for technology adoption or support for research and development, can encourage HAL to invest in automation.
	- Trade agreements can shape the business environment for HAL, affecting the availability of resources, market access, and competition.
	- HAL can support startups and collaborate with entrepreneurial ventures to access cutting-edge technologies, disruptive ideas, and novel solutions that can enhance automated manufacturing processes. (Interviewee 2, 6, 8, 11, 12).[34]
5., (12), Manager Airport Authority Chennai Airport	- Political instability or unfavorable regulations may hinder progress.
	- Economic factors, such as market demand, cost structures, labor availability, and currency fluctuations, can influence the success of automated manufacturing.
	- Encouraging entrepreneurship and innovation can foster a conducive ecosystem for automated manufacturing.
	- HAL's competitive strategy in the aerospace industry plays a vital role in the success of automated manufacturing.
	- By strategically positioning themselves and leveraging automation technologies, HAL can gain a competitive advantage, improve production efficiency, reduce time to market, and offer cost-effective solutions. (Interviewee 1, 5, 12, 15, 16).[35]

Table 1 Continued...

Interviewee Serial no, (Experience in years), Location Designation,	Main comments on automated manufacturing at Hindustan Aeronautics Ltd (HAL) (Other Interviewees in agreement to the comments)
6. , (10), Vice President Shipping Company UK	- Favorable trade agreements can facilitate the procurement of technology, components, and materials required for automated manufacturing, potentially reducing costs and expanding opportunities. - Environmental sustainability is becoming increasingly important for businesses worldwide. - HAL needs to evaluate the economic viability of implementing automation, considering factors like initial investment, operational costs, and potential cost savings in the long run. - HAL's commitment to reducing carbon footprint and adopting green practices can drive the integration of sustainable technologies in automated manufacturing. - This may include energy-efficient processes, recycling initiatives, and the use of eco-friendly materials. (Interviewee 3, 5, 7, 9, 16).[36]
7. , (15), Vice President Operations, Aircraft Manufacturer, France	- Alignment between the product design and the manufacturing process, ensuring that the design is compatible with the automated manufacturing systems - Automation and robotics are vital for streamlining manufacturing processes. - Hindustan Aeronautics needs to invest in advanced automation technologies and robotics systems to increase productivity, reduce manual labor, and minimize errors. - The choice of materials plays a crucial role in automated manufacturing. Hindustan Aeronautics needs to select materials that are suitable for automation, ensuring they can be effectively processed and assembled by the automated systems. - Implementing automated systems allows for faster and more precise production, leading to higher output and enhanced competitiveness (Interviewee 3, 5, 7, 10, 15).[37]
8. , (17), Vice President, Banking Sector, Singapore	- Helps optimize production efficiency, reduce errors, and enhance overall product quality. - Compatibility between the materials and the manufacturing processes leads to improved production speed, accuracy, and cost-effectiveness. - Hindustan Aeronautics should focus on implementing sustainable practices, such as energy-efficient machinery, waste reduction, and recycling initiatives. - By prioritizing sustainability, the company can minimize its environmental impact, improve resource efficiency, and meet evolving regulatory requirements. - Successful automated manufacturing requires a focus on effectiveness, which involves optimizing production processes to achieve the desired outcomes efficiently (Interviewee 1, 4, 6, 9, 14).[38]
9. , (17), Entrepreneur and Owner, Electronics, Abu Dhabi	- Hindustan Aeronautics should continually monitor and evaluate the performance of its automated systems, identify bottlenecks, and make improvements to ensure smooth operations and high-quality output. - The visual appeal and quality of the finished products can significantly impact customer perception and market competitiveness. - Hindustan Aeronautics should integrate super finishing techniques and aesthetic considerations into its automated manufacturing processes to ensure customer satisfaction. - This involves implementing lean manufacturing principles, regularly analyzing data, and actively seeking feedback from customers and employees. - By continuously improving processes, Hindustan Aeronautics can stay ahead of the competition and achieve long-term success in automated manufacturing. - The psychological well-being of employees is essential for successful automated manufacturing. Hindustan Aeronautics needs to consider factors such as job satisfaction, motivation, and engagement. - A positive work environment can boost morale, productivity, and overall job satisfaction, leading to better performance in automated manufacturing (Interviewee 4, 5, 9, 11).[37]
10. , (11), Consultant Logistics Middle East, Qatar	- Hindustan Aeronautics should embrace a culture of continuous improvement, constantly seeking ways to enhance its automated manufacturing capabilities. - Automation can lead to changes in job roles and responsibilities, which may cause stress among employees. - Managing stress effectively helps maintain employee well-being and ensures a smooth transition to automated manufacturing. - Employee well-being is crucial for the success of automated manufacturing. Hindustan Aeronautics should prioritize the physical and mental health of its workforce. - This can be achieved through initiatives like ergonomic workstations, health programs, and work-life balance measures. - A healthy and satisfied workforce contributes to improved productivity and quality in automated manufacturing. (Interviewee 2, 4, 12, 13).[39]

Table 1 Continued...

Interviewee Serial no, (Experience in years), Location Designation,	Main comments on automated manufacturing at Hindustan Aeronautics Ltd (HAL) (Other Interviewees in agreement to the comments)
11. , (12), CTO, Software Development and Solutions, Onam	- Hindustan Aeronautics should manage stress levels by providing appropriate training, support, and resources. - Employee performance is critical for the success of automated manufacturing. - Hindustan Aeronautics should invest in comprehensive training programs to equip employees with the necessary technical skills, troubleshooting capabilities, and understanding of automated processes. - The overall dynamics within the organization impact the success of automated manufacturing. Hindustan Aeronautics should foster a culture of collaboration, open communication, and teamwork. - (Interviewee 1, 6, 14, 16).[40]
12. , (16), Operations Head, Ports and Customs, Government KSA	- Clear roles and responsibilities, effective leadership, and a supportive work environment are essential for successful implementation and operation of automated systems. - Proper training is vital to ensure that employees can effectively operate and maintain automated manufacturing systems. - Hindustan Aeronautics should provide adequate training and up skilling opportunities to ensure that employees have the necessary skills to work with automated systems. - Well-trained employees contribute to increased efficiency and reduced downtime in automated manufacturing. - The implementation of automated manufacturing should align with the requirements and specifications of 5th generation aircraft. - Hindustan Aeronautics needs to ensure that their automated systems are capable of producing components and systems that meet the advanced technological standards of these aircraft. (Interviewee 1, 3, 11, 15).[41]
13. , (12), Vice President Aircraft Maintenance, UK	- Regular performance evaluations and feedback help identify areas for improvement and support continuous growth and development. - Adapting automated manufacturing to the specific needs of 5th generation aircraft will contribute to the success of the implementation. - Effective cost management, including investment in appropriate technology and equipment, training, and maintenance, is essential for the successful implementation and long-term sustainability of automated manufacturing. - The automation of manufacturing processes should be aligned with superior design principles. - Hindustan Aeronautics needs to ensure that the automated systems are capable of producing components and products that meet the highest design standards in terms of quality, precision, and performance. - Superior design is crucial for the success of automated manufacturing and the overall quality of the aircraft produced. (Interviewee 2, 4, 7, 8, 11).[42]
14. , (8), Entrepreneur and Owner, Private Jets, Hongkong	- The cost of implementing automated manufacturing is a crucial factor. Hindustan Aeronautics should carefully consider the budget allocated for this purpose. - The implementation of automated manufacturing can have a significant impact on the export potential of Hindustan Aeronautics. - If the automated systems enable cost-effective production with high-quality standards, it can enhance the competitive edge of the company in global markets. - The ability to meet market demands efficiently and effectively will contribute to the successful implementation of automated manufacturing. - The successful implementation of automated manufacturing should align with customer requirements and expectations. - (Interviewee 6, 8, 13, 16).[43]
15. , (14), Vice President Oil and Natural Gas, India	- Customer satisfaction is crucial for the success of the company, and automated manufacturing should contribute to fulfilling customer needs. - Compliance with aviation norms and regulations is essential in the implementation of automated manufacturing. - Hindustan Aeronautics must ensure that the automated systems and processes meet all required certifications and safety standards. - Hindustan Aeronautics needs to ensure that the automated systems can produce aircraft components and systems that meet the highest standards of quality, reliability, and safety. - Adhering to aviation norms is critical for the success of automated manufacturing and the overall safety and reliability of the aircraft produced. - The involvement of management is crucial for the successful implementation of automated manufacturing (Interviewee 3, 4, 7, 9, 10).[44]
16. , (10), HOD Aircraft Design and Structural Development, France	- Hindustan Aeronautics should have strong leadership and management support to drive the implementation process effectively. - Management involvement ensures proper resource allocation, decision-making, and coordination among different departments, resulting in successful outcomes in automated manufacturing. (Interviewee 4, 8, 11, 15).[45]

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Conclusion and recommendation

Implications of this research

The research on key factors driving potential future developments in automated manufacturing at HAL has significant implications. Firstly, it can enhance efficiency and productivity, leading to faster delivery and cost reduction. Secondly, it can improve product quality and precision, crucial in the aerospace industry. Moreover, it can reduce labor costs and address skill gaps, allowing for resource allocation to more complex tasks. Additionally, it highlights the need for up skilling and can create career growth opportunities. Lastly, successful implementation can serve as a model for the industry's advancement, fostering growth and attracting investments.[49]

Practical implications

The research study on key factors driving potential future developments in automated manufacturing at HAL has numerous practical implications. It provides insights that can guide informed decision-making regarding the adoption and integration of automation technologies. The research highlights the potential for increased efficiency and productivity, allowing HAL to identify areas that can benefit from automation and streamline operations. It emphasizes the importance of automation in ensuring consistent and accurate manufacturing, enabling HAL to enhance product quality and reliability. The research also underscores the potential for cost reduction through automated manufacturing, identifying tasks that can be automated to reduce labor costs and optimize resource utilization. It emphasizes the need for up skilling and reskilling the workforce to adapt to automation, enabling HAL to plan training programs and initiatives for career advancement. Successful implementation can position HAL as an industry leader and inspire other companies to adopt automation, driving the growth of the aerospace industry in India.[50]

Social implications

The research study on key factors driving potential future developments in automated manufacturing at HAL has significant social implications. It highlights the potential impact of automation on the workforce, with potential job displacement and changes in job roles and responsibilities. It is crucial for HAL and other organizations to consider the social impact and provide support to affected employees through retraining or alternative employment opportunities. The study emphasizes the need for up skilling and reskilling the workforce to adapt to automated manufacturing, which has implications for individuals to remain competitive in the job market. HAL can contribute by promoting skill development programs and collaborating with educational institutions. The adoption of automation can lead to increased productivity and cost reduction, but organizations need to be mindful of potential economic disparities and mitigate negative consequences through responsible management practices. The research also underscores the importance of technological literacy and ethical considerations. HAL can promote technological literacy and ensure responsible deployment of automated systems, addressing issues of data privacy, security, and human impact. In summary, the social implications include employment dynamics, skill requirements, economic disparities, technological literacy, and ethical considerations, which require proactive management for a positive societal impact.[51]

Managerial implications

The research study on key factors driving potential future developments in automated manufacturing at HAL has several managerial implications. It provides insights that managers can use to develop strategic plans for effective incorporation of automation technologies. Managers can identify areas where automation can enhance productivity, reduce costs, and improve efficiency. The study can guide goal-setting and objective development related to automation implementation. Automation can also lead to changes in job roles and responsibilities, requiring managers to assess the impact on the existing workforce and plan for skill gaps and retraining needs. They can use the study to identify specific skills required for successful implementation and develop strategies to address these requirements through training programs, hiring, or partnerships with educational institutions. Effective communication with employees is crucial, and the study can help managers explain the rationale behind automation and address any concerns or resistance. Collaboration and partnerships with external stakeholders, such as technology providers and educational institutions, are highlighted by the study as important. Managers can leverage this information to identify potential partners who can support HAL in implementing automation effectively. Responsible and ethical deployment of automated systems is emphasized, requiring managers to consider ethical implications and ensure alignment with organizational values through guidelines, policies, and procedures. In summary, the managerial implications include strategic planning, workforce management, change management, collaboration, and ethical considerations, enabling managers to make informed decisions and navigate automation implementation successfully.[52]

Limitations and future research

The contribution and originality- value of the research

The main contribution of this study is the development of a conceptual model based on the Human-Machine Interaction Theory using technology. It explores the challenges and issues faced by stakeholders in achieving successful automated manufacturing at HAL and gathers consensus from industry experts through primary research. To validate and test the conceptual model's reliability, the study utilizes PLS-SEM ADANCO and employs statistical quantitative methodology. Data is collected from different countries, relevant to the aviation and aircraft manufacturing sector, as experts are located worldwide. This is made possible by the collaboration of domain experts and working PhD students from different countries and domains, which is another significant contribution of this study. The study's objectives result in the integration of two theories, the Human-Machine Interaction Theory and Technology theory, yielding a new model for future research studies.

Conclusion

In conclusion, this research study on the key factors driving potential future developments in automated manufacturing at Hindustan Aeronautics Ltd (HAL) has made significant contributions to the field. Through the development of a conceptual model based on the Human-Machine Interaction Theory using technology, the study sheds light on the challenges and issues faced by stakeholders in achieving successful automated manufacturing at HAL. By gathering consensus from industry experts through primary research and utilizing statistical quantitative methodology to validate and test the conceptual model's reliability, the study provides valuable insights and recommendations for the future. The collaboration of domain experts and working PhD students from different countries and domains further enhances the study's credibility and contributes to its breadth of knowledge. The integration of the Human-Machine Interaction Theory and Technology theory in the conceptual model

paves the way for future research studies in the field. The study's findings highlight the importance of considering these key factors to drive potential future developments in automated manufacturing at HAL, ultimately enhancing efficiency, productivity, and overall success in the aviation and aircraft manufacturing sector. Overall, this research study serves as a valuable resource for HAL and other organizations in the industry, providing a foundation for informed decision-making and strategic planning in the pursuit of automated manufacturing advancements.

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None.

Conflicts of interest

The authors declare that there is no conflict of interest.

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