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Leveraging AI for Process Optimization: The Future of Quality Assurance in Lean Six Sigma

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ABSTRACT

The incorporation of Artificial Intelligence into Lean Six Sigma methodologies establishes a revolutionary process strategy that optimizes operations and maintains superior quality results. AI upgrades Lean Six Sigma processes through real-time data examination and AI-driven prediction models and automation capabilities for optimized decision-making and waste reduction and elevated output quality. Modern AI applications including machine learning and anomaly detection and process simulation tools fortify Lean Six Sigma's DMAIC cycle framework throughout Define, Measure, Analyze, Improve and Control phases. Companies benefit from AI implementation with its speed and precision in process improvements and expanded scalability yet they must address concerns regarding their data quality as well as integrating tools and building staff capabilities. This work investigates AI integration within Lean Six Sigma operations through real-world industrial examples as well as discussing essential training needs along with implementation resources. AI will transform Lean Six Sigma operations through its ability to produce smarter and more agile business organizations in upcoming decades.

INTRODUCTION

Organizations operating in today's competitive data-driven landscape need to actively find solutions to optimize operations while eliminating defects and improving product/service standards. Lean Six Sigma operates as a proven methodology which brings together Lean waste-cutting principles with

Six Sigma defect-prevention elements to become an established method for continuous enhancement [1]. The basic foundation of Lean Six Sigma depends on organized problem resolution and data-driven decision processes that reach operational excellence through systematic frameworks like DMAIC (Define, Measure, Analyze, Improve, and Control) [2].

Quality Assurance through Lean Six Sigma monitors process enhancement durability as well as operational standard fulfillment. The process includes active monitoring alongside validation methods along with documentation steps which show that products and services meet necessary requirements. Traditional QA approaches depend on historical data and reactive methods but these methods delay the recognition of issues while restricting the immediate opportunity for intervention [3].

The great power of Artificial Intelligence (AI) emerges to transform modern operations. The combination of data mining and machine learning and pattern recognition and real-time analytics features allows AI to serve as a proactive tool for both QA management and process optimization. AI combined with Lean Six Sigma possesses the ability both to expedite problem-solving efforts and identify potential quality problems early enough to implement preventive measures [4].

The growing challenges faced by businesses through operational complexities and evolving customer needs make AI integration into Lean Six Sigma a requirement rather than an optional investment. AI systems extract meaning from extensive datasets while detecting hidden patterns which leads to both procedural recommendations and potential automated fix implementations. Advances in quality assurance strategies transform this support function into a strategic enabler for both innovation and organizational speed [5].

The main scope of this research investigates the methods by which AI capabilities improve Lean Six Sigma stages as well as enhance quality monitoring while facilitating accelerated and expandable process development. The ability of organizations to successfully use AI positions them for enhanced competitive positioning alongside better customer satisfaction and continuous improvement development [6].

INDUSTRIES EXPERIENCE AN INCREASING PRESENCE OF ARTIFICIAL INTELLIGENCE DEVELOPMENT

Fundamentally transformed from academic concepts AI has become a business force shaping industries across all sectors during recent decades. AI transforms business operations because it efficiently handles excessive data while identifying meaningful patterns which results in automated decision support and delivers more efficient processes and innovative solutions. AI has advanced quickly through multiple industry domains including healthcare and manufacturing and finance and

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customer service [7].

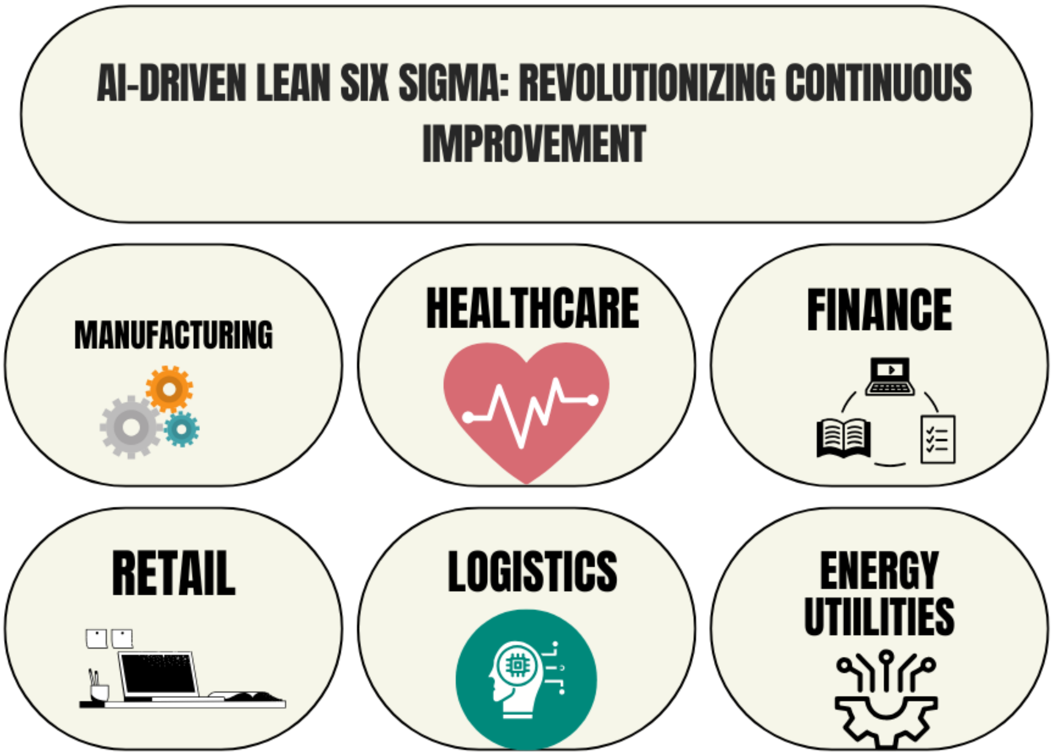

Figure: 1 showing AI driven lean six sigma revolutionizing continuous improvement

Artificial Intelligence describes machines or systems which execute jobs needing human intellect to complete them. The system performs four core functions that include problem-solving alongside language understanding and visual perception and decision-making activities. Industrial change today is led primarily by four significant AI technologies which comprise machine learning and natural language processing (NLP) and computer vision and robotics [8].

Machine Learning represents an essential AI subset that leads process optimization. Through analysis of historical data ML algorithms generate predictions as well as identify trends while recommending operational enhancements. Lean Six Sigma requires these capabilities because they enable organizations to spot operational weaknesses and foresee workspace breakdowns while optimizing their procedures in real time. Through continual data processing Machine Learning develops into a superior analytical tool that supports iterative improvement according to Lean Six Sigma principles [9].

Therough the application of Natural Language Processing companies have achieved significant changes in both data handling and customer contact methodologies. NLP performs text and speech analysis to extract valuable insights from customer feedback together with social media data along with email content and survey responses [10]. Through this analysis businesses gain better insight into customer emotional expressions to detect service defects that allow them to enhance their product or service offerings. NLP enables Lean Six Sigma practitioners to use it during the Define phase to collect precise information about customer needs and performance problems [11].

Through Computer Vision artificial intelligence systems gain the ability to process images and video data effectively. Manufacturing operations benefit from AI-enabled visual inspection techniques which identify production defects right when they appear to strengthen product quality assessment systems. This technology eliminates human inspections while it expedites production and raises accuracy standards which matches Lean Six Sigma's goal for defect reduction and waste elimination [12]. Robotics together with automation through AI applications have revolutionized the execution of repetitve activities. Logistics industries benefit from AI robots which optimize inventory management while using automated assembly automation to minimize human errors without sacrificing quality standards [13].

AI advancements in industry operations drive organizations to abandon outdated human-led systems and adopt innovative intelligent flexible systems. AI's technological growth will make it a major component within Lean Six Sigma practices to deliver enhanced process optimization accompanied by stronger quality assurance and continuous improvement capabilities [14].

ORGANIZATIONS CAN ACHIEVE BETTER RESULTS BY INTEGRATING ARTIFICIAL INTELLIGENCE SYSTEMS TO WORK ALONGSIDE LEAN SIX SIGMA

Artificial Intelligence technologies will revolutionize how businesses optimize their processes by creating a new era in Lean Six Sigma practice. AI alongside Lean Six Sigma methodology enables professional efficiency improvements and variation reduction by adding cutting-edge data analytics with automated algorithms and real-time monitoring across the entire improvement cycle process [15].

The Lean Six Sigma project framework consists of the five steps called Define, Measure, Analyze, Improve, and Control. Several AI-enabled approaches power up and quicken this improvement cycle. Natural Language processing technology helps organizations analyze service logs alongside social media and customer feedback to identify previously unseen service problems which result in more precise problem definitions [16]. Through operational data analysis AI systems provide complete stakeholder mapping capabilities while performing effective project prioritization. AI sensors combined with Internet of Things (IoT) devices collect uninterrupted real-time data streams.

Machine learning algorithms analyze massive quantities of information to detect essential performance indicators while measuring process fluctuations better than conventional sampling techniques. Analyze: When analyzing extensive and complex datasets AI systems possess a powerful capability to uncover hidden patterns together with connections and fundamental causes which typically evade human analysis. Data analytics alongside clustering methods deliver insights about concealed process inefficiencies and quality failures before they trigger actual outcomes [17].

Digital twins combined with process modeling tools allow AI to create simulations that test different improvement methods. Predictive models enable the system to assess optimal modifications which helps organizations avoid common trial-and-error approaches historically The control phase becomes possible through AI thanks to anomaly detection algorithms which allow continuous process monitoring. Through automated alert systems and adaptive control features organizations maintain their improved performance levels while keeping processes within defined control parameters [18].

Organizations embedding AI into Lean Six Sigma practices enable faster strategic decision-making and deeper insight generation while implementing smarter solutions to their operations. AI applications augment human operators in their work by directing them to strategic assignments instead of time-consuming data manipulation tasks [19].

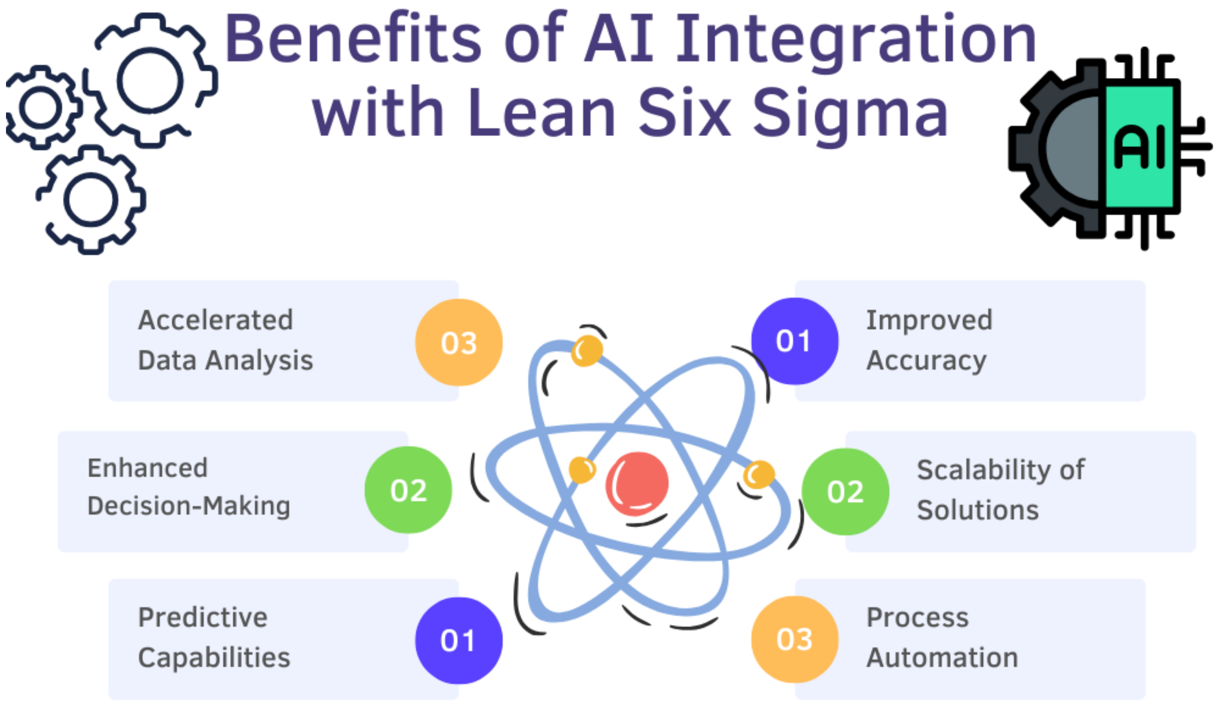

Figure: 2 showing benefits of AI integration

AI-DRIVEN QUALITY ASSURANCE

The process of Quality Assurance upholds prime status as a Lean Six Sigma cornerstone since it guarantees operations fulfill predicted objectives while maintaining improvement sustainability across time. Quality Assurance through traditional means repeats inspections and conducts manual testing and depends on historical data to track quality [20]. These methods deliver good results yet they do not follow current developments in real-time nor can they detect upcoming issues. Artificial Intelligence (AI) introduces essential revolutionary capabilities by transforming QA activities to be simultaneously efficient and anticipating possible issues [21].

AI-driven Quality Assurance uses machine learning (ML) analytics together with automation and data analytics to continuously track processes during real-time by detecting deviations while suggesting immediate remedies. The key strength of AI systems lies in their ability to process enormous datasets that include both organized and informal data obtained from production lines and customer information sources and sensor monitoring networks. AI detects quality problems earlier than standard methods which enables faster corrective measures [22].

The essential addition of AI to quality assurance practice includes predictive quality. AI implements machine learning algorithms to evaluate historical data that identifies quality challenges in advance. The technological identification of recurring process defects and operational inefficiencies permits AI systems to alert teams about vulnerable processes which allows them to initiate preventive actions [23]. The combination of AI systems and sensor data helps manufacturing environments identify potential machine failures that enable the prevention of costly downtime and keep end products inside established quality specifications [24].

AI brings the ability to detect anomalies as one of its primary advantages. The current quality assurance practices use established threshold measurements and manual checks to detect anomalies. Through continuous data learning AI systems adjust and enhance their anomaly detection models. By doing this it spots both new quality problems and minor quality deviations which standard systems would otherwise ignore. The automatic detection of patterns stands out in operations with changing conditions which manual quality checks would fail to detect [25].

AI-powered automated testing methods lead to rapid quality checks and validation processes during product or service assurance procedures. Without human involvement automated systems execute multiple tests simultaneously to check results against targets which leads to the detection of issues. Automated QA testing combines with artificial intelligence to cut traditional testing expenses and boost the precision and consistency of quality exams [26]. Through the implementation of AI-driven

QA systems quality assurance transitions from manual reactive inspections into a proactive system delivering real-time intelligence. Through the implementation of AI-driven QA systems organizations can preserve high quality standards from design until delivery while minimizing production mishaps and decreased efficiency. The combination of AI technology with QA methods matches Lean Six Sigma objectives by creating ongoing improvement systems that guarantee quality standards remain at their specified levels [27].

CASE STUDIES AND INDUSTRY APPLICATIONS

AI-driven quality assurance and process optimization improve business functions across multiple industries because of their incredible power when Lean Six Sigma enables their application. The following examples illustrate powerful industry applications of these methods as well as compelling case studies:

AI has revolutionized manufacturing quality control through real-time operational monitoring systems combined with predictive equipment maintenance capabilities. The automotive manufacturer uses AI sensors and cameras installed on their production line to monitor components and detect potential defects [28]. Visual data undergoes analysis from machine learning algorithms to discover defects which typical human inspectors would overlook. The implementation of AI technology helps detect defective components early so that high-quality items continue toward future production stages. AI systems reduce machinery downtime through sensor data analysis which simultaneously improves overall equipment effectiveness (OEE) [29].

The healthcare industry achieves advantages from AI-based quality assurance efforts that serve both medical device manufacturing and patient care activities. AI tools equipped with artificial intelligence perform real-time oversight of medical device assembly lines resulting in manufacturing devices within precise regulatory requirements [30]. The analysis of patient care data through AI leads to process optimization within hospitals by finding places where improvements are needed. Predictive models enable hospitals to allocate beds optimally and schedule staff and direct patients most efficiently which sustains high-quality medical care. These applications use Lean Six Sigma processes with AI analysis for waste minimization operations and they provide real-time system learning to improve performance continuously [31].

Artificial intelligence systems do two things for service organizations: they analyze customer feedback to guarantee quality standards and they optimize operational delivery processes. A worldwide airline organization leverages artificial intelligence to evaluate customer satisfaction by assessing social media sentiments beside surveys and direct end-user responses. Artificial intelligence systems use their analytics tools to detect often-seen service problems and create automated solutions

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for better customer experience quality [32]. Through their partnership AI systems help airlines optimize their operations while lowering service problems and offering better customer experiences through real-time process enhancement.

AI IMPLEMENTATION IN LEAN SIX SIGMA DEMONSTRATES BOTH STRATEGIC ADVANTAGES AND OPERATIONAL DIFFICULTIES

The Implementation of Artificial Intelligence (AI) with Lean Six Sigma methodologies delivers substantial advantages while transforming business strategies for process enhancement quality control and ongoing improvement requirements. Organizations need to resolve multiple obstacles to achieve total AI potential while implementing Lean Six Sigma practices [33].

The real-time functionality of Artificial Intelligence speeds up process optimization through its data analysis abilities and decision-making capabilities. Through sophisticated machine learning systems businesses can efficiently scan thousands of linked datasets and automatically detect patterns which generates actionable insights at a significantly faster pace than traditional analysis [34]. Businesses can initiate rapid implementation of changes and optimize processes dynamically by using reduced data collection and analysis and decision-making times. The expedient nature of AI is vital for industries that require speed such as manufacturing together with healthcare facilities [35].

Through AI-based systems quality assurance technology detects flaws which human workforce might have overlooked during inspection activities. The accuracy of process observation becomes enhanced through AI techniques which include predictive system failure modeling combined with instant anomaly detection capabilities. Through AI-enabled processes companies can achieve better quality and fewer mistakes while minimizing waste which supports both Lean Six Sigma priorities regarding defect reduction and continuous improvement [36].

AI allows organizations to transform their decision-making processes from reliance on judgments into data-based choices. The analysis of historical data through AI models produces detailed evidence to determine why issues occur while making prediction and recommending procedural enhancements. The data-centric method amplifies the effectiveness of Lean Six Sigma processes so business entities can select improvements supported by evidence-based facts [37].

AI helps expand quality assurance processes and process optimization work across entire large organization networks. AI automation tools perform repetitive tasks like data collection testing and process monitoring without any human involvement. Human resources gain capacity to perform strategic functions so the organization can further optimize its entire operational process [38].

AI systems use high-quality precise data to develop significant information from it. Databases with inconsistent information or missing pieces or data bias can result in technology generating inappropriate decisions and flawed recommendations. Before implementing AI tools organizations need to validate that their datasets are clean and dependable. AI adoption brings special difficulties to companies employing outdated systems and maintaining separated data domains among departments [39].

A successful implementation of AI into existing Lean Six Sigma practices demands strategic planning. Installing AI into operations requires organizations to update outdated systems and workplace traditions to function properly together with AI capabilities. Future success depends on thorough change management strategies which teach staff members to adopt AI tools while recognizing their supportive role to Lean Six Sigma tools. Companies need to spend substantial resources on software acquisitions alongside hardware implementation and staff training programs when deploying AI technologies [40]. Many businesses face difficulties when attempting to allocate funds for AI implementation particularly those with constrained financial capabilities. Organizations face challenges in effectively using AI because of skill shortages but can solve the problem through investments that build new talent or recruit specialized personnel to handle AI implementation and refinement [41].

AI-based models powered by machine learning frequently operate as "black boxes" which produces decisions while preventing users from seeing the decision-making process. AI's lack of transparency concerning its decision-making processes creates doubts about both decision accountability and system transparency. Organizations operating under strict regulatory rules such as healthcare or finance must verify that AI-generated decisions maintain transparency as well as fit ethical protocols and compliance standards [42]. Incoming organizations must recognize both positive impacts and difficulties to properly prepare for AI integration in Lean Six Sigma practices so they can unlock its maximum value alongside solving probable issues.

DEVELOPMENT AND USE OF FUTURE-ORIENTED SKILLS

The integration of AI technology with Lean Six Sigma for process optimization and quality improvement creates an increasing requirement for new tools as well as skill development. Organizations implementing AI technologies into Lean Six Sigma programming need domain expertise in process improvement alongside technical knowledge of AI alongside competence in tools which support these methods. The following list represents vital skills together with tools that will shape future quality assurance practices in Lean Six Sigma [43].

Both Lean Six Sigma and AI need a solid grasp of data as their cornerstone foundation. Professional competence requires the ability to execute data analysis from varied sources together with the capabilities to determine trends and develop usable outcomes. Lean Six Sigma professionals must master statistical techniques for their discipline while developing capability with next-generation AI platforms that handle predictive analytics and machine learning applications. Knowledge of data visualization methods helps practitioners show information in an understandable way to stakeholders [44].

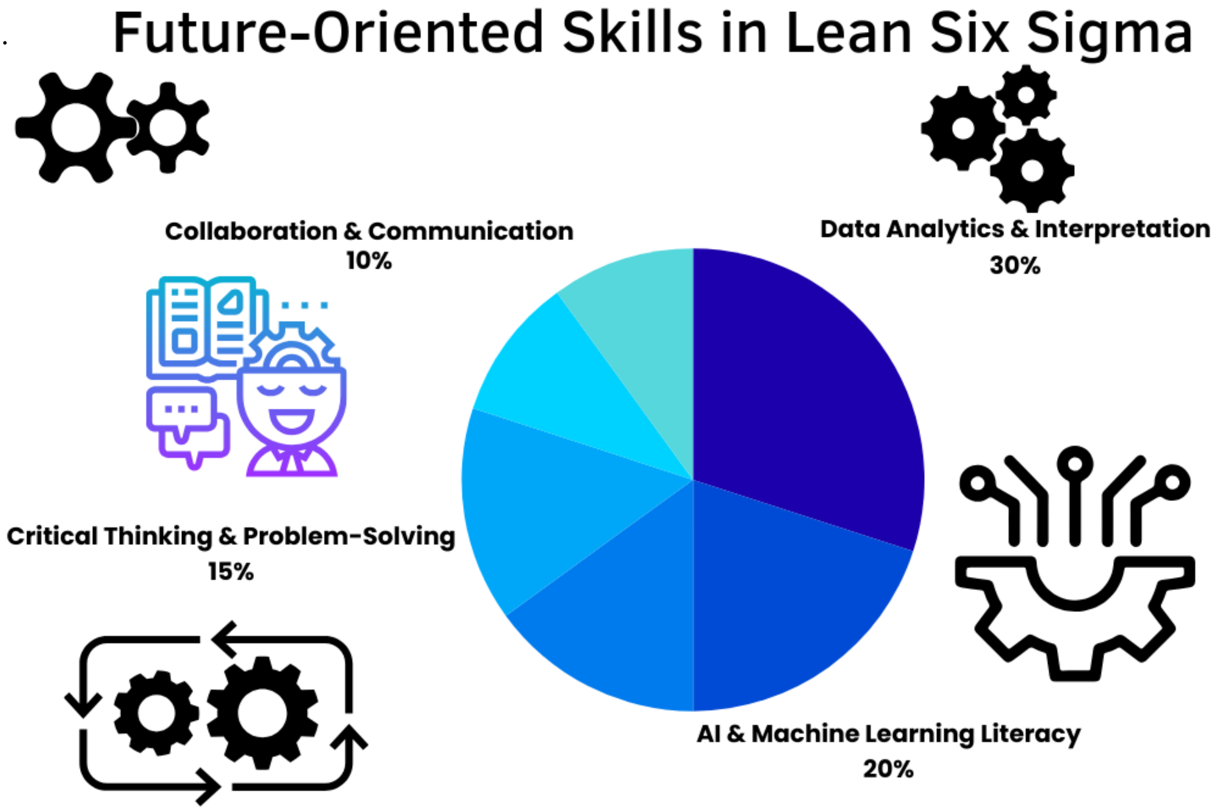

Figure: 3 showing future orientated skills in leans six sigma

Lean Six Sigma practitioners handle optimization procedures yet must achieve essential competency in AI technology and machine learning fundamentals to optimize their technology usage. The fundamental understanding of supervised and unsupervised learning together with neural networks and natural language processing (NLP) concepts represents essential knowledge. By understanding the basics of AI and machine learning professionals can make informed decisions together with AI experts during the implementation of quality assurance tools [45].

In the present era of automation-focused quality assurance operational excellence requires professionals to develop digital tool mastery that supports automated processes. Expertise in robotic process automation (RPA), cloud-based platforms and AI-powered software tools boosts productivity noticeably [46]. The valuable skill for professionals working with Lean Six Sigma methodologies is their experience using software platforms which unify AI with Lean Six Sigma approaches.

AI-driven Lean Six Sigma transformations require professionals to handle changes effectively for success. AI implementation requires leaders to guide diverse staff teams beyond resistance within their institutions while matching AI advances to workplace culture. The successful adoption of AI solutions depends on tight collaboration between data scientists, Lean Six Sigma experts and IT teams to prevent AI from disrupting processes but instead optimize them [47].

The powerful analytic tools offered by IBM Watson and Google AI and Microsoft Azure enable machine learning and predictive analytics and process optimization operations. These platforms provide pre-packaged data solutions alongside analytic capabilities for Lean Six Sigma initiatives that generate insights needed to drive better process choices and performance outcomes. Business processes can be evaluated beforehand through tools like Arena Simulation and Simul8 which allow real-world analysis per simulations made [48]. The virtual testing space created by these tools lets organizations examine different process modification methods with artificial intelligence automation before they implement changes into reality thereby reducing potential risks while enhancing the effectiveness of process improvements [49].

The AI-powered tools Celonis and Automation Anywhere enable businesses to discover operational inefficiencies in their processes while conducting automation tasks. Real-time process visibility through these platforms helps businesses uncover bottlenecks then uses automatic actions to apply corrections which establishes them as vital Lean Six Sigma resources [50]. The combination of properly developed skills and appropriate tools allows organizations to ready their teams against future AI integration in Lean Six Sigma while delivering better process optimization and quality assurance outcomes more efficiently.

CONCLUSION

Organizations now use Artificial Intelligence (AI) to revamp their Lean Six Sigma practices for improving operational methods and quality control procedures. Businesses can achieve incredible efficiency while maintaining exceptional accuracy through their use of Lean Six Sigma methodologies coupled with Artificial Intelligence capabilities for continuous process improvement. AI makes the traditional Lean Six Sigma system more powerful by helping organizations uncover risks in advance while it enhances workflow optimization and delivers improved quality results at faster speeds.

AI-based DMAIC cycle enhancement enables organizations to transform reactive operational approaches into predictive along with real-time solutions through Define, Measure, Analyze, Improve, and Control phases. AI analytical tools including machine learning and predictive analytics along with anomaly detection enhance performance by prompting quicker decisions and automated processes while producing more precise operational improvements. These tools demonstrate substantial influence in multiple sectors including manufacturing and healthcare and service industries which results in improved quality outcomes together with increased customer satisfaction. AI implementation inside Lean Six Sigma offers organizations both promising opportunities alongside complex technical problems to solve. Artificial Intelligence brings clear benefits to process optimization through speed and accuracy improvements along with automation but organizations need to manage obstacles related to data quality alongside process integration and cost outlook and skill requirements. Strategic measures involving AI and data analytics specializations along with up-to-date tools coupled with management changes for smooth system integration will help organizations defeat these implementation challenges.

Advancements in AI technology for Lean Six Sigma operations will transform business operational excellence practices during forthcoming years. Professionals with proper skills and tools will lead this transformation by building smarter more agile organizations. Advanced AI technology will progressively enhance process optimization along with quality assurance capabilities thus delivering organizations premium competitive advantages in today's data-centric business environment. AI and Lean Six Sigma present integrated frameworks that lead the evolution of process optimization while creating improved methods for quality assurance and continuous enhancement. Organizations that effectively combine their skills with strategic tools will sustain competitive success when they implement these methodologies correctly.

REFERENCES

[1]. Antoine M, Ralite F, Soustiel C, Marsac T, Sargos P, Cugny A, et al. Use of metrics to quantify IMRT and VMAT treatment plan complexity: A systematic review and perspectives. Phys Med 2019;64:98–108. https://doi.org/10.1016/j. ejmp.2019.05.024.

[2]. Kamperis E, Kodona C, Hatziioannou K, Giannouzakos V. Complexity in radiation therapy: it's complicated. Int J Radiat Oncol Biol Phys 2020;106:182–4. https://doi.org/10.1016/j.ijrobp.2019.09.003.

[3]. Hernandez V, Hansen CR, Widesott L, B¨ ack A, Canters R, Fusella M, et al. What is plan quality in radiotherapy? The importance of evaluating dose metrics, complexity, and robustness of treatment plans. Radiother Oncol 2020;153:26–33. https://doi.org/10.1016/j.radonc.2020.09.038.

[4]. Jurado-Bruggeman D, Hern´ andez V, Saez ´ J, Navarro D, Pino F, Martínez T, et al. Multi-centre audit of VMAT planning and pre-treatment verification. Radiother Oncol 2017;124:302–10. https://doi.org/10.1016/j.radonc.2017.05.019.

[5]. Craft D, Süss P, Bortfeld T. The tradeoff between treatment plan quality and required number of monitor units in intensity-modulated radiotherapy. Int J Radiat Oncol Biol Phys 2007;67:1596–605. https://doi.org/10.1016/j.ijrobp.2006.11.034.

[6]. Ho, Y. C., Chang, O. C., Wang, W. B. (2008). An empirical study of key success factors for six sigma green belt projects at an Asian MRO company. Journal of Air Transport Management, 14(5), 263-269.

[7]. Ortiz, C. A. (2012). The psychology of lean improvements: Why organizations must overcome resistance and change the culture. Productivity Press (Routledge)

[8]. Antony J, Coronado RB. Design for six sigma. Manufacturing Engineer. 2002; 81(1):24-6. 2. Breckenridge A, Breckenridge L, Singh K, Wilson S. Lean Six Sigma in the pharmaceutical industry. Journal of Pharmaceutical Innovation. 2012;7(1):52-8

[9]. Shah R. Six Sigma in pharmaceutical manufacturing. Quality Progress. 2014; 47(10):42-9. 4. Chopra S, Meindl P. Supply Chain Management: Strategy, Planning, and Operation. 6th ed. Boston: Pearson; 2015.

[10]. Lee J, Davari M, and Singh J. Pharmaceutical manufacturing: Optimizing using Six Sigma techniques. Pharmaceutical Development and Technology. 2010; 15(5):502-10.

[11]. Stephenson DS. Regulatory implications of Six Sigma in pharmaceutical quality systems. Journal of Regulatory Science. 2015;1(3):1-9.

[12]. Chai T, Draxler RR. Root mean square error (RMSE) or mean absolute error (MAE)? Geoscientific Model Development Discussions. 2014; 7(1):1525-34.

[13]. Ben-Daya M, Kumar U, Murthy DNP. Introduction to Maintenance Engineering: Modeling, Optimization, and Management. 1st ed. Hoboken: Wiley; 2016.

[14]. Montgomery DC. Design and Analysis of Experiments. 9th ed. Hoboken: Wiley; 2017. 10. Madan S, Madan S. Artificial intelligence and its role in pharmaceutical research and development. Drug Development Research. 2020; 81(2):118-27.

[15]. Russell S, Norvig P. Artificial Intelligence: A Modern Approach. 4th ed. Boston: Pearson; 2020. 12. Goodfellow I, Bengio Y, Courville A. Deep Learning. Cambridge: MIT Press; 2016. 13. Lipton ZC. The mythos of model interpretability. ACM Queue. 2018; 16(3):31-57.

[16]. Molnar C. Interpretable Machine Learning. 2nd ed. Lulu.com; 2020. 15. Chui M, Manyika J, Miremadi M. What AI can and can't do (yet) for your business. McKinsey Quarterly. 2018;1-6. 16. Topol EJ. High-performance medicine: The convergence of human and artificial intelligence. Nature Medicine. 2019; 25(1):44-56.

[17]. Beam AL, Kohane IS. Big data and machine learning in health care. JAMA. 2018;319(13):1317-8. 18. Jiang F, Jiang Y, Zhi H, et al. Artificial intelligence in healthcare: Past, present and future. Stroke and Vascular Neurology. 2017; 2(4):230-43.

[18]. Parikh RB, Teeple S, Navathe AS. Addressing bias in artificial intelligence in health care. JAMA. 2019; 322(3):237-8.

[19]. Lai, E., Yun, F., Arokiam, I., & Joo, J. (2020). Barriers affecting successful lean implementation in Singapore's shipbuilding industry: A case study. Operations and Supply Chain Management: An International Journal, 13(2), 166–175. https://doi.org/10.31387/oscm0410260

[20]. Sony, M. (2020). Design of cyber-physical system architecture for Industry 4.0 through Lean Six Sigma: Conceptual foundations and research issues. Production & Manufacturing Research, 8(1), 158–181. https://doi.org/10.1080/21693277.2020.1774814

[21]. Lambri N, Hernandez V, S´ aez J, Pelizzoli M, Parabicoli S, Tomatis S, et al. Multicentric evaluation of a machine learning model to streamline the radiotherapy patient specific quality assurance process. Phys Med 2023; 110: 102593. https://doi.org/10.1016/j.ejmp.2023.102593.

[22]. Chan GH, Chin LCL, Abdellatif A, Bissonnette J, Buckley L, Comsa D, et al. Survey of patient-specific quality assurance practice for IMRT and VMAT. J Appl Clin Med Phys 2021;22:155–64. https://doi.org/10.1002/acm2.13294.

[23]. Chiavassa S, Bessieres I, Edouard M, Mathot M, Moignier A. Complexity metrics for IMRT and VMAT plans: a review of current literature and applications. Br J Radiol 2019;92:20190270. https://doi.org/10.1259/bjr.20190270

[24]. Younge KC, Matuszak MM, Moran JM, McShan DL, Fraass BA, Roberts DA. Penalization of aperture complexity in inversely planned volumetric modulated arc therapy: Penalization of aperture complexity in inversely planned VMAT. Med Phys 2012; 39:7160–70. https://doi.org/10.1118/1.4762566.

[25]. Osman AFI, Maalej NM. Applications of machine and deep learning to patientspecific IMRT/VMAT quality assurance. J Appl Clin Med Phys 2021; 22:20–36. https://doi.org/10.1002/acm2.13375.

[26]. Marsac T, Camejo AB, Chiavassa S, Jan S, Lorand H, Moignier A. An effective and optimized patient-specific QA workload reduction for VMAT plans after MLCmodelling optimization. Phys Med 2023; 107:102548. https://doi.org/10.1016/j.ejmp.2023.102548.

[27]. Noblet C, Maunet M, Duthy M, Coste F, Moreau M. A TPS integrated machine learning tool for predicting patient-specific quality assurance outcomes in volumetric-modulated arc therapy. Phys Med 2024; 118:103208. https://doi.org/10.1016/j.ejmp.2024.103208.

[28]. Cavinato S, Bettinelli A, Dusi F, Fusella M, Germani A, Marturano F, et al. Prediction models as decision-support tools for virtual patient-specific quality assurance of helical tomotherapy plans. Phys Imaging Radiat Oncol 2023; 26: 100435. https://doi.org/10.1016/j.phro.2023.100435.

[29]. Bossuyt E, Nevens D, Weytjens R, Taieb Mokaddem A, Verellen D. Assessing the impact of adaptations to the clinical workflow in radiotherapy using transit in vivo dosimetry. Phys Imaging Radiat Oncol 2023; 25:100420. https://doi.org/10.1016/j.phro.2023.100420.

[30]. Mans A, Rozendaal R, Janssen T, Damen E, Kaas J, Van Mourik A, et al. Reduction of systematic dosimetric uncertainties in volumetric modulated arc therapy triggered by patient-specific quality assurance. Phys Imaging Radiat Oncol 2022; 21:6–10. https://doi.org/10.1016/j.phro.2022.01.001.

[31]. Wall PDH, Hirata E, Morin O, Valdes G, Witztum A. Prospective clinical validation of virtual patient-specific quality assurance of volumetric modulated arc therapy radiation therapy plans. Int J Radiat Oncol Biol Phys 2022; 113:1091–102. https://doi.org/10.1016/j.ijrobp.2022.04.040

[32]. D'Andreamatteo A, Ianni L, Lega F, Sargiacomo M. Lean in healthcare: A comprehensive review. Health Policy 2015; 119:1197–209. https://doi.org/10.1016/j.healthpol.2015.02.002

[33]. Tennant G. Six sigma: SPC and TQM in manufacturing and services. Aldershot: Gower; 2001. [24] Chassin MR. Is health care ready for Six Sigma quality? Milbank Q 1998;76: 565–91. https://doi.org/10.1111/1468-0009.00106.

[34]. Mancosu P, Nicolini G, Goretti G, De Rose F, Franceschini D, Ferrari C, et al. Applying Lean-Six-Sigma Methodology in radiotherapy: Lessons learned by the breast daily repositioning case. Radiother Oncol 2018;127:326–31. https://doi.org/10.1016/j.radonc.2018.02.019.

[35]. Liu S, Bush KK, Bertini J, Fu Y, Lewis JM, Pham DJ, et al. Optimizing efficiency and safety in external beam radiotherapy using automated plan check (APC) tool and six sigma methodology. J Appl Clin Med Phys 2019; 20:56–64. https://doi.org/ 10.1002/acm2.12678.

[36]. Simons PAM, Houben R, Vlayen A, Hellings J, Pijls-Johannesma M, Marneffe W, et al. Does lean management improve patient safety culture? An extensive evaluation of safety culture in a radiotherapy institute. Eur J Oncol Nurs 2015;19: 29–37. https://doi.org/10.1016/j.ejon.2014.08.001.

[37]. Mancosu P, Russo S, Antonucci AR, Stasi M. Lean Thinking to manage a national working group on physics aspects of Stereotactic Body Radiation Therapy. Med Phys 2021; 48:2050–6. https://doi.org/10.1002/mp.14783.

[38]. Lodhi SK. Synaptic Harmonies: Applying Graph Coloring Algorithms to Mental Health AI Systems. Global Journal of Emerging AI and Computing. 2025 Jan 26;1(1):83-91.

[39]. Scaggion A, Fusella M, Agnello G, Bettinelli A, Pivato N, Roggio A, et al. Limiting treatment plan complexity by applying a novel commercial tool. J Appl Clin Med Phys 2020;21:27–34. https://doi.org/10.1002/acm2.12908.

[40]. Zeb S, Lodhi SK. AI and Cybersecurity in Smart Manufacturing: Protecting Industrial Systems. American Journal of Artificial Intelligence and Computing. 2025 Apr 7;1(1):1-23.

[41]. Crowe SB, Kairn T, Kenny J, Knight RT, Hill B, Langton CM, et al. Treatment plan complexity metrics for predicting IMRT pre-treatment quality assurance results. Australas Phys Eng Sci Med 2014; 37:475–82. https://doi.org/10.1007/s13246-014-0274-9.

[42]. He J, Baxter SL, Xu J, et al. The practical implementation of artificial intelligence technologies in medicine. Nature Medicine. 2019; 25(1):30-6.

[43]. Finlayson SG, Subbaswamy A, Singh K, et al. The clinician and dataset shift in artificial intelligence. The Lancet Digital Health. 2021; 3(1)

[44]. Krittanawong C, Zhang H, Wang Z, et al. Artificial intelligence in precision cardiovascular medicine. Journal of the American College of Cardiology. 2017; 69(21):2657-64.

[45]. Jiang H, Liao Y, Feng W, et al. Machine learning-based CT radiomics model for predicting histopathological subtype of meningioma. European Journal of Radiology. 2019; 116:1-7.

[46]. Petersen C, DeMuro PR. Legal and regulatory considerations for the use of artificial intelligence in healthcare. Journal of the American College of Radiology. 2020; 17(9):1109-14.

[47]. Aziz A, Ahmad M. Role of AI and machine learning in pharmaceutical manufacturing and quality control. Journal of Pharmacy and Bioallied Sciences. 2020; 12(1):1-6.

[48]. Kuziemsky CE, Gogia SB, Househ M, et al. balancing health information exchange and privacy governance from a global perspective. Yearbook of Medical Informatics. 2018; 27(1):48-55.

[49]. Alloghani M, Al-Jumeily D, Mustafina J, et al. A systematic review on supervised and unsupervised machine learning algorithms for data science. Supervised Learning Algorithms. 2020; 1(1):3-21.

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[50]. Ahmed Z, Mohamed K, Zeeshan S, et al. Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine. Database: The Journal of Biological Databases and Curation. 2020;2020(1)