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RCMOS - Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

Year V, v.1, n.1, Jan/July 2025. | submission: 08/06/2025 | accepted: 10/06/2025 | publication: 12/06/2025

Technical drawing and industry 4.0: integration with simulation, 3D printing and augmented reality

Technical drawing and industry 4.0: integration with simulation, 3D printing and augmented reality

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SUMMARY

This article aims to analyze the integration of technical drawing with emerging technologies of Industry 4.0, with an emphasis on the application of tools such as computer simulation, 3D printing, and augmented reality. Based on a literature review, the main transformations that have occurred in the practice of technical drawing, traditionally manual, and its transition to interactive digital platforms based on CAD and BIM software were identified. It was observed that the digitalization of technical drawing contributes significantly to communication between teams, component prototyping, product customization, and advanced visualization of complex systems. In addition, the incorporation of artificial intelligence, the Internet of Things, and cyber-physical systems has expanded the capacity for automation, monitoring, and control of industrial processes, demanding a new approach from engineering professionals. Augmented reality, in particular, has been applied to technician training, real-time visualization, and maintenance support. It is concluded that the modernization of technical design is an irreversible trend, essential for increasing competitiveness, efficiency and innovation in the industrial sector, requiring continuous investments in training, technological infrastructure and curricular adaptation in technical and higher education.

Keywords: Technical drawing; Industry 4.0; Augmented reality.

Abstract

The present article aims to analyze the integration of technical drawing with the emerging technologies of Industry 4.0, with an emphasis on the application of tools such as computer simulation, 3D printing, and augmented reality. Based on a literature review, the main transformations in the practice of technical drawing—traditionally manual—were identified, along with its transition to interactive digital platforms based on CAD and BIM software. It was observed that the digitalization of technical drawing significantly contributes to team communication, component prototyping, product customization, and advanced visualization of complex systems.
Furthermore, the incorporation of artificial intelligence, the Internet of Things, and cyber-physical systems has expanded the capabilities for automation, monitoring, and control of industrial processes, demanding a new approach from engineering professionals. Augmented reality, in particular, has been applied for technical training, real-time visualization, and maintenance support. It is concluded that the modernization of technical drawing is an irreversible trend, essential for increasing competitiveness, efficiency, and innovation in the industrial sector,

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requiring continuous investment in training, technological infrastructure, and curriculum adaptation in technical and higher education.

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1 INTRODUCTION

In recent decades, the industry has undergone a profound structural transformation and technological, driven by the growing integration of digital resources into production processes. Automation, previously restricted to repetitive tasks controlled by isolated systems, has given way to to interconnected smart grids, capable of analyzing data in real time, predicting failures and optimize production autonomously. This evolution marks the transition from traditional manufacturing for industrial models based on advanced technologies such as the Internet of Things (IoT), artificial intelligence, cloud computing and big data, consolidating the concept of Industry 4.0 (Souza; Bonetti, 2019). In this scenario, classic engineering activities, such as technical drawing, have been reconfigured to dialogue with these innovations, becoming a key piece in the integration between design, digital manufacturing and smart maintenance.

Industry 4.0, in turn, represents a new stage of the Industrial Revolution, characterized by comprehensive digitalization and intelligent automation of production systems. Technologies such as additive manufacturing, augmented reality and cyber-physical systems expand the possibilities of control, customization and efficiency in industrial environments. This paradigm has promoted significant changes in maintenance engineering and technical design, requiring the updating of traditional practices and tools to meet the new demands of market (Simonetti, 2023).

Technical drawing, an essential element in communicating projects and specifications in engineering, began to be widely developed with the use of CAD (Computer-Aided) software Design), which enable precise three-dimensional modeling, detailed structural analysis and integration with other digital technologies. In this context, computer simulation stands out as a strategic resource to anticipate the behavior of systems before their implementation, while 3D printing enables rapid prototyping and on-demand production of components personalized, reducing deadlines and costs (Gibson; Rosen; Stucker, 2021).

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Furthermore, augmented reality has expanded the potential of technical drawing by allowing the superimposition of digital elements on the physical environment, providing a visualization interactive and accurate real-scale projects. Its application in maintenance engineering has been explored to guide technicians in the field through dynamic visual instructions, which contributes to reducing errors and increasing operational efficiency (Bezerra, 2024).

This article aims to analyze, through a bibliographic review, the integration of technical drawing with emerging technologies of Industry 4.0, especially simulation, 3D printing and augmented reality, discussing the impacts of this convergence on the practice of maintenance engineering. The aim is to contribute to the understanding of new paths of technical design and its strategic relevance in the context of the digital transformation of the industry.

2 TECHNICAL DRAWING IN THE INDUSTRIAL CONTEXT

The evolution of design in technology was marked by a transition from methods traditional to digital innovations. Initially, design in technology was focused on functionality, with early tools and machines prioritizing efficiency and utility.
As technology advanced, design began to incorporate aesthetics, ergonomics and experience of the user, making the products not only functional but also attractive and easy to use. The The Industrial Revolution marked a significant turning point as production techniques in mass allowed the standardization of design, bringing form and function to a wider audience (Catanzaro, 2015).

In the 20th century, the advent of digital technology revolutionized design once again. The emergence of computers and software allowed designers to explore new possibilities, leading to the development of user interfaces, graphic design and digital media.
This era saw the rise of iconic design philosophies such as minimalism and mind-centered design.
in the user, which have since become fundamental to modern technological products (Oliveira, 2019). Today, design in technology is at the forefront of innovation. Technologies such as AI and machine learning have further expanded these possibilities, enabling solutions for more personalized and adaptable design. Real-time data integration and customer feedback user enabled the creation of highly responsive and engaging designs.

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As technology advances and user expectations change, design practices need to adapt. Modern design needs to balance visual appeal with functionality and ease of use. Key considerations include responsive layouts, user interfaces, intuitive interfaces and efficient navigation. Designers are tasked with meeting client goals and user needs while ensuring that their creations are effective and relevant. As the technology continues to evolve, design will also advance to meet the demands of a world dynamic. In the next paragraph, we will see how design has progressed over time.

2.1 The Transformation of Technical Drawing in the Digital Age

Technical drawing, traditionally done manually, has undergone a profound change transformation with the advent of digital technologies. The introduction of design software Computer-aided development (CAD) represented a decisive milestone in the modernization of practices project management. These systems provided greater precision, agility in the production and editing of drawings, as well as greater reliability in communication between engineers, architects and designers. According to Rossi, Ribeiro and Bruscato (2025), CAD not only replaced the drawing board, but also made it possible to develop more complex and detailed projects, promoting the integration between different disciplines of technical knowledge.

With technological advancement, tools such as Building Information Modeling (BIM) and parametric modeling were integrated into the project development process, allowing a vision more holistic, dynamic and interactive of the represented systems. BIM stands out for enabling the simultaneous management of geometric, structural and functional information, being today a requirement in various sectors of engineering and civil construction. According to Holanda (2018), These technologies allow greater control over the life cycle of projects, reducing significantly reducing rework and promoting resource optimization from the design phase until execution.

The incorporation of artificial intelligence (AI) and machine learning learning) in technical drawing software has enabled the automation of repetitive tasks, in addition to generating optimized design solutions based on historical data. This approach has been used to improve workflows, predict structural behaviors and autonomously suggest design alternatives. Buga, Borzan and Trip (2025) highlight that AI

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applied to technical design is transforming creative processes, freeing professionals to focus on strategic and higher value-added activities, such as product innovation products and continuous process improvement.

Another fundamental aspect of this transformation is cloud digitalization, which has significantly facilitated collaboration between multidisciplinary teams, even when geographically dispersed. Cloud-based collaborative platforms such as Autodesk Construction Cloud and Trimble Connect enable different professionals to work together simultaneously on the same digital model, promoting real-time synchronization and change tracking. This connectivity is crucial to meeting project demands complex and dynamic in the era of Industry 4.0, in addition to reducing communication failures and accelerating development cycles (Wang *et* al., 2023).

The evolution of technical design is not limited to digitalization and network integration. Emerging technologies such as augmented reality (AR) have been gaining ground in environments design and academic projects, with applications ranging from three-dimensional visualization of systems to technical training. According to Bezerra (2024), AR provides more immersive experiences and understandable, especially in technical education, where abstract concepts can be visually materialized, facilitating learning and content retention.

Additive manufacturing, with an emphasis on 3D printing, has proven to be an extension natural of digital technical drawing. The possibility of producing physical parts directly from computational models are revolutionizing prototyping and customization at scale industrial. Feriotti *et al.* (2021) show that 3D printing not only reduces production time, prototype manufacturing, as well as allowing rapid performance testing and precise adjustments at low cost, favoring continuous innovation.

Leading engineering firms have embraced reality-based immersive solutions augmented for real-time project review and collaboration. Tools like Campfire allow collaborative viewing of full-scale three-dimensional CAD models, facilitating communication between engineers, designers and clients. According to Tadeja, Seshadri and Kristensson (2019), these approaches have been especially useful in the aerospace sector, where precision and anticipating errors is crucial to the success of projects.

These innovations have significantly expanded the role of technical drawing, which leaves from being a simple graphical representation tool and becomes a central element

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RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

planning, control and execution of industrial systems. The digital environment allows performance simulations, structural analyses and design validations still in the conceptual phase, increasing the reliability and efficiency of the products developed.

The digital revolution in technical drawing has also strongly influenced education professional. Virtual and augmented reality-based teaching platforms such as Unity Reflect and SketchAR have been applied to teach drawing practices in an interactive and attractive. This has contributed to the training of professionals who are better prepared to deal with demands of Industry 4.0, with mastery of digital tools and the ability to adapt to constant technological transformations (Beck; Costa, 2020).

From an environmental and energy point of view, digital modeling makes it possible to carry out thermal, energy and structural performance simulations in the early stages of the project. This approach allows for more sustainable and informed decisions, contributing to the reduction of environmental impact and promoting more responsible practices within the industry. The use of technologies such as CAD and BIM in this context have proven effective in implementing strategies aimed at green engineering (Amaral, 2018).

Mass customization has also become a reality with the advancement of design digital technician. Companies can tailor their products to individual preferences and needs of consumers without compromising production efficiency, thanks to the combined use of parametric modeling, 3D printing, and component databases. This flexibility contributes to greater competitiveness in the global market, where customization is increasingly valued (Bezerra, 2024).

The transformation of technical drawing represents a true paradigm shift in way in which engineering projects are conceived, developed and executed. It requires updating continuous professional skills, mastery of new technologies and a critical stance towards of the possibilities and challenges brought by digitalization. Today's professional needs be able not only to use digital tools, but to integrate them strategically into industrial processes.

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2.2 Integration of Technical Design with Emerging Technologies in Industry 4.0

Industry 4.0 represents a significant transformation in the industrial landscape, driven by the integration of technologies such as the Internet of Things (IoT), advanced automation and cyber-physical systems. Industrial production faces an urgent demand to adapt to this new reality to remain relevant and efficient. Along this path, there is a need to overcome cultural resistance in organizations, provide adequate professional training to deal with with emerging technologies, face the financial costs associated with implementing these innovations and ensure cybersecurity in an increasingly interconnected environment (Sousa *et* al., 2024).

The integration of technical drawing with emerging technologies such as augmented reality (AR), has been explored to provide interactive visual instructions to field technicians, increasing the accuracy and efficiency of interventions. AR allows the overlay of digital information about the physical environment, facilitating visualization and decision-making in real time. The application of emerging technologies creates a new approach to controlling production processes, providing real-time synchronization of flows and allowing the unitary and personalized manufacturing of products. The new tools imply the adoption of new business models, directly impacting technical design and its integration with digital technologies (Bomfim *et* al., 2024).

The integration of cyber-physical systems (CPS), Internet of Things (IoT) and Internet of Things (IoT) Services (IoS) has been fundamental in the consolidation of smart factories, characterizing the Industry 4.0. These technologies enable real-time interconnection and communication between machines, systems and human beings, promoting more efficient and adaptable production to market demands. The decentralization of decision-making processes is one of the main consequences of this integration, requiring a reconfiguration of the technical design to meet this new productive reality (Nascimento, 2018).

In this context, cyber-physical systems play a crucial role in monitoring and control physical processes through computer networks, creating a virtual copy of the reality that allows decentralized and autonomous decisions. IoT facilitates communication between CPS and humans, while IoS provides internal and external organizational services, used by all participants in the value chain. This technological structure requires that the

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technical design is adapted to incorporate these new functionalities and ensure the interoperability between the various systems involved (Nascimento, 2018).

The decentralization provided by Industry 4.0 also implies a change in the way decisions are made within organizations. With the capacity of systems cyberphysicists to make decisions autonomously, there is a reduction in the need for intervention human, allowing for more agile and efficient production (Santos *et* al., 2018). This change requires that the technical design be developed in a way that allows this autonomy, incorporating sensors and actuators that enable the collection and analysis of data in real time.

The decentralization of production processes requires greater flexibility and adaptability of production systems. The technical design must be able to reflect this flexibility, allowing rapid changes and adaptations in production processes to meet to market demands. This implies greater integration between technical design and digital technologies, such as 3D modeling and virtual simulation, which allow testing and validation different production scenarios before their implementation.

According to Alves, Pinheiro and Silva (2023), the implementation of Industry 4.0 also brings challenges related to data security and privacy. With the interconnection of systems and the mass collection of data, it is essential that the technical design incorporates security measures that ensure the protection of information and the reliability of systems. This includes the use of secure communication protocols, data encryption and authentication mechanisms and user authorization.

Adapting technical design to the reality of Industry 4.0 requires a change in training and qualification of the professionals involved. It is necessary that engineers and technicians are familiar with new technologies and are able to integrate them efficiently in production processes. This implies an update of academic curricula and ongoing training programs that prepare professionals for the challenges of the fourth industrial revolution.

2.3 Applications of Augmented Reality in Technical Design and Industry 4.0

AR has established itself as an essential tool in the digital transformation of industry, especially in the context of Industry 4.0. Its ability to overlay information

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RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

digital to the physical environment allows a more intuitive and efficient interaction between operators and complex systems. In technical drawing, AR facilitates the three-dimensional visualization of projects, allowing engineers and technicians to identify and correct possible failures even in the design phase design, reducing costs and rework. This integration between the virtual and real worlds provides a deeper understanding of projects, optimizing the process product development (Dal Forno *et* al., 2021).

Additionally, AR has been successfully applied in industrial environments for training and employee training. By simulating real machine operation and maintenance situations, workers can gain practical skills in a controlled and safe environment. This approach reduces learning time and increases knowledge retention, preparing students professionals to deal with complex equipment and risk situations. The use of AR in industrial training represents a significant advance in the formation of qualified labor to meet the demands of Industry 4.0 (Fuchter; Schlichting, 2018).

In the context of production, AR has been used to assist in the assembly of components and equipment maintenance. Through devices such as glasses intelligent, operators receive real-time visual instructions, guiding them step by step through the tasks to be performed. This assistance reduces errors, increases efficiency and improves quality of the final product. Companies in the automotive sector, for example, have adopted AR to optimize their assembly processes, highlighting the benefits of this technology in the production line (Gélio; Giocondo Caesar, 2022) .

According to Souza *et* al. (2021), predictive maintenance is another area that has been benefited from the application of AR. Sensors installed on machines collect data in real time, which are analyzed to predict failures and schedule maintenance before downtime occurs unexpected. AR complements this process by providing detailed views of the parts internal equipment, allowing technicians to quickly identify components that require attention. This proactive approach to maintenance contributes to the reduction of operating costs and increased asset availability.

The integration of AR with other emerging technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) has further expanded its applications in industry. IoT allows the collection and transmission of data in real time, while AI analyzes this information to provide valuable insights. AR, in turn, presents this data in a visual and interactive way,

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facilitating decision-making by operators and managers. This technological convergence is shaping the future of industrial operations, making them smarter and more responsive (Birth, 2018).

Despite advances, the implementation of AR in the industry faces challenges, such as the high cost of acquiring equipment and the need for adequate infrastructure. In addition, the Adapting workers to new technologies requires investment in training and change cultural in organizations. Overcoming these barriers is essential for companies to be able to fully take advantage of the benefits of AR and remain competitive in the Industry 4.0 scenario.

3 CONCLUSION

The analysis carried out throughout this study shows that technical drawing, traditionally used as a representation and communication tool in engineering, has been progressively transformed by the incorporation of emerging Industry 4.0 technologies. The digitalization of processes, combined with integration with CAD software, simulation tools, augmented reality and 3D printing, not only modernized production methods, but It also expanded the capacity for analysis, prototyping and making more accurate technical decisions and fast. This evolution reflects a paradigmatic shift in the role of technical drawing, which ceases to be a static element and becomes a dynamic and interactive component in systems productive.

It was observed that the application of these technologies offers substantial benefits to maintenance engineering and industry in general, such as cost reduction, increased operational efficiency and increasing the quality of the products developed. Tools such as Augmented reality has shown promise in training professionals and in the execution of more precise interventions, while additive manufacturing enables mass customization and agility in prototyping. Integration with cyber-physical systems and platforms based on The cloud has also enabled collaborative work in real time, connecting professionals in different locations and promoting greater flexibility and adaptability in project management industrial.

The integration between technical design and Industry 4.0 technologies represents not only a technical advance, but a strategic necessity in view of the demands of the current market. To

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For this process to be consolidated, continuous investment in training is essential professional, updating of pedagogical practices in technical and higher education, as well as policies to encourage technological innovation. The future outlook points to an increasingly industrial environment increasingly intelligent, digital and sustainable, where technical design will play a central role in articulation between design, production and maintenance, consolidating itself as an essential link in digital transformation in engineering.

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