CENTER FOR
AUTOMOTIVE
RESEARCH

Digital Transformation and Its Impact on Quality Assurance Whitepaper

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ABOUT THE AUTHORS

The Center for Automotive Research is an independent non-profit that produces industry-driven research and fosters dialogue on critical issues facing the automotive industry and its impact on the U.S. economy and society. CAR researchers closely track current and future global automotive industry and technology trends and assess their impacts. CAR researchers also study international collaborations and stay abreast of changes in international trade and regulatory environments, the development of technology standards, and the deployment of new vehicle technologies.

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EXECUTIVE SUMMARY

The conversion brought forth by digital transformation and advanced technologies has made a tremendous impact on the way manufacturers process and manage their organizations. While the strategies of agile and modern management systems, specifically quality management, are the result of digital conversion, there is still limited understanding and unclear identification in this new era of quality assurance impact. With the development of digital methodologies, the classical system of operating businesses has been disrupted. As a result, many organizations are in the process of reacting to digitization by utilizing enhanced business platforms and rebuilding the waterfall approach to the agile approach.

The interviews conducted during this research stated that companies are mainly motivated by a focus on process improvement and demands communicated by their customers. The aim of this paper is to describe how digitization and transformation to new technologies can impact the quality assurance system of the manufacturers, specifically the automotive industries.

Competition amongst quality and consumer satisfaction are the most challenging factors in each industry. This project will focus on the influence of progressive technologies and ingenuity on a variety of modern, agile, and advanced processes in the automotive industry. Table 1 illustrates the gathered conclusion of this research.

Table 1: Research Questions and Answers

	Research question	Respond based on the research
1	What is digital transformation and the key challenges in automotive industries as it relates to the quality assurance segment?	The primary objective of quality assurance is to evaluate the entire activities in the processes and procedures of a system and improve quality, including training, documentation, monitoring, and audit. As customer demand and expectation increase the digital transformation journey becomes critical for organizations to compete. The key challenge in this journey is to overcome the organization's acceptance of the new technology, integrating, transitioning, updating the old systems, and training the workforce.
2	What are the current challenges in quality management?	Implementing a reliable quality management system can overcome the current challenges in manufacturing organizations which are: . Excess documentation . Supply chain complexity . Lack of quality equipment . Not enough implication and communication . Lack of resources and time . No training and development

3	How can digital quality management resolve the current issues?	A digital, advanced, and automated management system in quality utilizes a cloud-based methodology to coordinate the planning, team collaboration, monitoring, and delivery of the projects based on the digital data on a network of remote servers.
4	What are the benefits of Industry 4.0 and its relation to Quality 4.0?	As indicated the digital transformation return of investment is favorable in areas of safety, quality, delivery, cost, morale, and environment and can be scaled based on the size of the company.
5	How can digital transformation and smart manufacturing improve the internal and external user experience?	Enhanced quality control techniques impact product design, end-user expectation, operational performance, and customer satisfaction. Automated systems and artificial intelligence will constantly provide an additional surge in the quality of products or the quality of life of end-users

The research paper includes the investigation and the introduction of numerous developments and inventions in manufacturing organizations in the last few years. The paper begins by introducing the current challenges in existing processes and the impact of digital methodologies in planning and management – specifically in quality management. This qualitative research will also incorporate a summary that covers the digital transformation and the optimizations in the quality assurance sector of the automotive field.

- **Industry Focus:** Technology and Innovation
- **Research Focus:** Automotive Industries

The summary of this project will benefit educators within the advanced technology field, manufacturing stakeholders, as well as management. The research will be presented to educate the audience about introducing artificial modern technologies in order to enhance the efficiency, effectiveness, and competitiveness of the organization.

INTRODUCTION AND BACKGROUND

DIGITALIZATION AND ARTIFICIAL INTELLIGENCE

Artificial Intelligence or AI is a wide-ranging branch of computer science and is also known as machine intelligence. AI is defined as building intelligent machines that are capable of performing tasks that typically need human involvement.

The development of artificial intelligence and autonomous services are progressively taking over humans' tasks. Certain computer activities with artificial intelligence are invented for speech recognition, learning, and planning. The main focus of technological innovation is to accomplish a major benefit for human health, well-being, and time efficiency. With the enormous technological improvement, fulfilling a function and performing some tasks which could only be operated by a human with specialized knowledge and valuable experiences has been taken over with programmed machinery and robots. Autonomous and driverless cars, Industry 4.0 with robotic technologies in today's manufacturing world, electronic and automatic identification technologies, and computerized devices in logistics for efficiency and error reduction are some of the obvious examples of artificial intelligence [1].

Although programmed machinery increases artificial intelligence, it is still difficult to ensure sufficient evidence for demonstrating a complete substitution i.e. AI cannot replace all aspects of human cognition tasks.

The automotive industry is at its crossroads where new technologies such as artificial intelligence (AI), machine learning (ML), and high-performance computing (HPC) are leading innovations that fulfill the consumers' expectations. Digital transformation is a critical factor for automakers and suppliers, which involves product design processes, manufacturing methodologies, operation, sales, and marketing.

With increased production speed, agile innovation cycles, and enhanced databases, the automotive industry's manufacturers aim to stay relevant in a fast-moving marketplace by embracing digital transformation. The end goal of digital conversion or any other IT initiative is to enhance customer experience without any risk to the quality and to deliver an exceptionally smooth user experience [8].

This research is based on qualitative methodologies to provide an overview of digital transformation in automotive industries and its impact on quality assurance. The focus of this paper is on how managing the quality of automotive products and processes is deeply changed by digital transformation.

RESEARCH AIMS AND OBJECTIVE

The overall objective of the research is to gather the impact of digital transformation on the quality assurance segment in the automotive industry as well as its opportunities and risks. Methodologically, the research is based on a literature review that includes sources from both academic and professional authors and is structured along the research questions outlined in the next section.

The main focus of this research is to understand the contribution of advanced technologies to automotive industries and how digital, automated, and modern technologies can impact the quality of products and processes.

Research Questions

To achieve the purpose of this research, several research questions have been established. The research questions were identified to create a clear understanding and insight into digital transformation, digital quality management, as well as their relationship to the Industry 4.0, Quality 4.0, and user experience based on the smart manufacturing methodology. The questions will be answered in sections in chapters 2 and chapter 3. The key questions for this research are:

1. What is digital transformation and the key challenges in automotive industries as it relates to the quality assurance segment?
2. What are the current challenges in quality management?
3. How can digital quality management resolve the current issues?
4. What are the benefits of Industry 4.0 and its relation to Quality 4.0?
5. How can digital transformation and smart manufacturing improve the internal and external user experience?

POTENTIAL BENEFITS OF THIS RESEARCH

This research will provide insight and information about digital conversion and its impact on automotive industries. By providing the knowledge about the challenges in the current quality management system and the opportunities for improvement in the processes, the research will deliver a description of advanced technology in the quality segment, which could benefit practitioners, researchers, and automotive stakeholders to visualize possible opportunities for improvement in quality management and quality control processes. In addition, the literature review will illustrate an understanding of the impacts of digitalization, artificial intelligence, the internet of things, and data analytics in the automotive industry.

LITERATURE REVIEW

The literature review and the interview responses focused on three critical factors. These factors are (a) the application of Industry 4.0, digitalization of quality management and its impact on organizations, (b) the digital conversion, and the challenges as it relates to the human resources, and (c) the effect of new technologies on end-user experience.

DEFINING DIGITAL TECHNOLOGIES AND DIGITAL TRANSFORMATION

Digital transformation is about disruptive methodologies and new business models to increase productivity. The innovative character of digital transformation is one of the critical challenge factors for organizations. Despite all the transformation disruption, industry companies realize that, just like every other digital sector, they must be transformed to meet customer demands and improve the customer experience while they aim at strengthening their position in the marketplace and getting ahead in the competitive business world. Therefore, automotive manufacturers have been integrating advanced technologies and new innovations into all aspects of their operations. The emergence of the new methodologies brings new insight into the product and its production process and may even influence the value of the existing product.

The workforce culture clarity and acceptance of digital transformation require a different view of defining digitization as a disruptive or incremental change process. The process starts with the adoption of advanced and digital methodologies, then evolves into the implicit holistic conversion of an organization.

Among other characteristics of digital transformation, machine learning enables greater collaboration across IT, finance, supply chain, and production department through ubiquitous access to data. As an example, identifying the product defects in the manufacturing lines before they become costly product recalls eliminates waste of rework, repair, and negative impact on productivity [9].

DIGITAL QUALITY MANAGEMENT

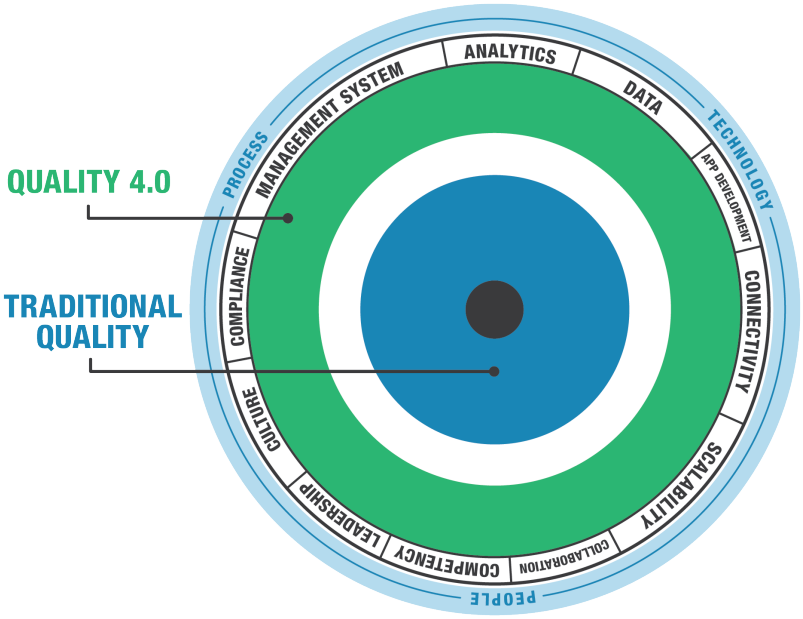
A digital, advanced, and automated management system in quality is defined as a cloud-based methodology to coordinate the planning, team collaboration, monitoring, and delivery of the projects based on the digital data on a network of remote servers. Digitalization in the quality control environment provides the capability of continuous improvement guidance by defining the process standards, recognizing the opportunities for enhancement, and utilizing digital solutions. Advanced analytics accelerate the quality control by discovering the process inefficiencies and agile

decision-making based on the data trend and summaries. Utilizing the digital methodologies in the quality control sector requires data-driven technologies. Digitization in the quality management system is referred to as micro-level engagement of collected digital data and quality tools to provide an advanced managerial instrument in the digital era [2].

INDUSTRY 4.0 AND QUALITY 4.0

The fourth industrial revolution is based on the integration of digital technology and smart manufacturing, which enables the industries to increase flexibility in the manufacturing processes. The main focus of industry 4.0 includes improving productivity and efficiency while enhancing flexibility and agility to increase profitability and morale in different parts of the organization. Industry 4.0 is based on greater connectivity which aims toward technological progress in different areas such as data analytics, data collection, and data transformation.

Figure 1: From Traditional Quality to Quality 4.0; Source: *Quality Concepts Home Blog*



Big data analysis, the internet of things, autonomous system, machine learning, cloud computing, and augmented reality are all representative of digital conversion and have become a necessity for manufacturers, including automotive industries in order to adapt to new business market requirements. Due to the demand in customer expectations, quality is a focused philosophy of every company in the industry. The dynamic expansion of the internet accelerated innovation impacts all sectors in industries by connecting human resources, machines, and data in new methodologies to make everything more accessible. From the quality perspective, utilizing Industry 4.0 strategies leads to Quality 4.0 which in turn has a direct impact on the culture of the organization, the collaboration manners, leadership, and compliance.

Quality 4.0 blends modern methodologies with traditional quality technologies to achieve a new optimum in operational performance and innovative processes. Quality 4.0 involves principles to represent a way to maximize the quality and value of the products by eliminating current barriers due to the lack of communication while increasing automated activities such as agile data analytics [4].

USER EXPERIENCE, BUSINESS MODEL CHANGE WITH SMART MANUFACTURING

The primary focus of digitization in business is to provide efficiency and improvements in operations by eliminating human errors, decreasing nonvalue-added activities, and enhancing communication methodologies. Internal and external customer experience is an essential factor in business that plays a vital role in digital conversion. Technological enhancement and advanced customer experience have raised the standard for the digital user experience. This makes it crucial to optimize the end-to-end user/customer experience in every digital methodology.

Digital conversion utilizes business technologies to facilitate business models and open innovations. Industry 4.0 relates to smart manufacturing; it requires the development of open business models and planning, which supports the implementation of advanced methodologies and innovation [11].

THE IMPORTANCE OF QUALITY ASSURANCE IN THE DIGITAL TRANSFORMATION PROCESS

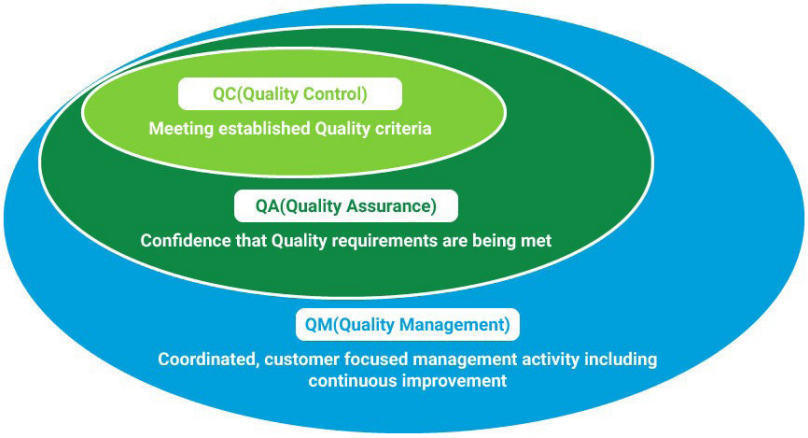
The return of investment from implementing the new methodology and advanced innovation in quality assurance and the testing processes is favorable. This will require a clear understanding of the organization's current quality opportunity, including the unfavorable financial impact. The investments can be optimized based on the company's size and budget. Quality assurance and processes are essential to encounter any challenges as early as possible in the process development to prevent any damage on a bigger scale later on.

DEFINITION OF QUALITY ASSURANCE IN MANUFACTURING

As most readers know, quality assurance (QA) is a way of preventing defects and is defined as

a division under quality management. The main focus of QA is providing quality standards by maintaining the quality requirements in the manufacturing organizations. The primary objective of quality assurance is to evaluate the entire activities in the processes and procedures of a system and improve quality, including training, documentation, monitoring, and audit.

Figure 2: Definition of Quality Assurance in Manufacturing; *Source: Nimbly Technologies*



As shown in Fig. 2, quality assurance is the first step to be completed before quality control. By identifying the customer's needs, QA establishes a standard for developing and manufacturing reliable products. This type of proactive management system will lead to an increase in customers' confidence and a company's credibility [12].

CURRENT QUALITY MANAGEMENT CHALLENGES

Throughout the manufacturing processes, problems may occur that will directly affect final production. Manufacturing issues are defined as defects, deficiencies, or variations in the final products. Interruptions along the supply chain, long lead time, and inventory problems are some of the significant causes of the manufacturing process dilemma. These manufacturing issues impact the quality management system. Based on the interviews done during this research, the quality management system is challenged in other aspects of the processes.

Below is a list of quality management problems experienced in the manufacturing organizations:

1. Excess documentation
2. Supply chain complexity
3. Lack of quality equipment
4. Not enough implication and communication
5. Lack of resources and time
6. No training and development

Implementing a reliable quality management system is a crucial step toward the success and competitiveness of the business. Advanced, enhanced, and updated quality management systems can boost the value of the end product or services, make the entire team accountable and improve the organization's reputation. Utilizing a reliable data gathering system and formalizing the right information helps to be more efficient and provides an easier communication path. Digitization and adoption of new technologies aim in enhancing the current issues by improving the auditing efficiencies. Ultimately, training is a crucial factor that needs to be documented and must demonstrate all the requirements for the tasks. Training in the advanced methodologies and continual opportunities for further development needs to be part of the business model and the organization's operation system.

DIGITAL TRANSFORMATION WITH ALIGNMENT OF HUMAN RESOURCES

Companies in the automotive industries initiated the digitization and architecture of smart plants by utilizing robots on assembly lines. This technique helps to increase productivity, improves ergonomics for associates, and eliminates non-value-added activities. In other words, digitalization increases system efficiencies by moving the objects autonomously based on the cloud-based data from the internet of things and neural network algorithms. The cloud-based data and machine learning lead to managing the production line activities such as planning, scheduling, maintaining the operation of factories, and detecting problematic parts in an agile and faster way. Intelligent and smart manufacturing methodologies such as sensors are capable of gathering data about vehicle quality performance. The cloud-based data analyzes the results to discover the potential source of issues by notifying the system, to prevent the rework or repair costs.

The strategies of digital transformation are based on the replacement of humans in the factories by advanced methodologies, machines, robotic solutions, digital systems, or artificial intelligence technologies. The critical factor of this approach is the engagement of the associates in the transformation of the factory. Human resources and people operations should ensure that workforce is receiving the proper training and professional development to be aligned with the modification and improvements throughout the organization. Digital transformation endows the early identification of potential issues and enables precise and high-quality work by decreasing the potential for human error and fatigue.

DIGITAL TRANSFORMATION AND OPTIMIZATION IN QUALITY ASSURANCE

Digital transformation will provide the ability for organizations to vitalize internal and external customers. Generally, Quality Assurance (QA) is the process of detecting defects and preventing potential repairs, issues, and waste in future products. The digital conversion, along with the transformation of automated technology and a self-understanding of the field, is the drive to

lead the quality control process. On the other hand, advanced user experience and customer satisfaction are the decisive influencing factors. To keep the competitiveness level in the business, it is not sufficient to simply provide quality and performance of the end products. For automotive industries, it is very crucial to concentrate on product testing and presenting the relevant data, which leads to contributing to sustainable business growth.

Meeting the expectations of the advanced customer needs requires agile and modern methodologies. Upgraded technologies increase the necessity for IT enhancement to improve the processes and boost quality assurance measurement. Innovation, process improvement, increased adoption of artificial intelligence, machine learning for automated testing, and new business models are some of the decisive factors to optimize the quality assurance of a manufacturing organization.

Ultimately, improving the automation and enhancement of quality assurance leads to the progress at each individual process checkpoint while eliminating waste and non-value-added activities.

KEY USE CASES IN THE AUTOMOTIVE INDUSTRY

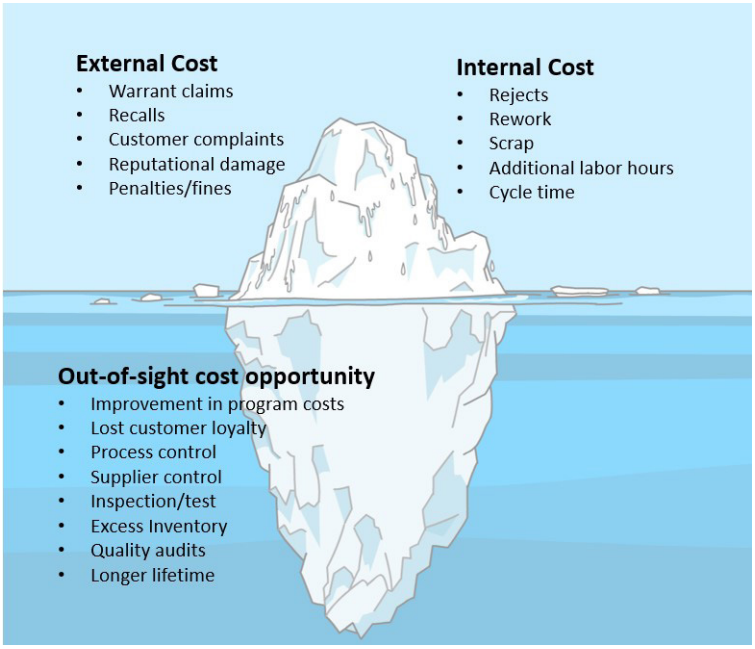
In the automotive industry, the smart manufacturing system utilizes the Internet of Things (IoT), machine monitoring system, sensor technology, big data, and cloud computing to transmit and process the data in the real-world system to be analyzed simultaneously. This chapter provides an understanding of cloud-based systems for quality assurance improvement and the crucial quality variables. Providing examples for computer visioned quality inspection and performance monitoring showcase an insight into predictive maintenance and remote diagnosis by utilizing digital technologies in automotive industries. The case studies collected results from Infor Drives and Cloudera.

UNDERSTANDING QUALITY VARIABLES

In any manufacturing operation, quality control is a managed process to establish a methodology to ensure the final product is free from defects and operational issues and based on the customer requirements. Quality variables define as gathered details about data that involve the performance information in an operation. Material, management, market, machine, and methodologies are the most effective factors in the quality of the product. In the automotive industry, the quality control process involves rigorous testing routines to achieve excellent engineering, safety, and comfort for the end-user. Quality event forensic analysis, throughput optimization, quality inspection, process

control, equipment monitoring, predictive maintenance, and warranty analytics are some of the crucial challenging areas in manufacturing and quality management system.

Figure 4: Cost of Quality; *Source: SSCG Automotive Manufacturing Quality Management*



Based on the iceberg analogy, the cost of quality is defined as the wasted cost associated with defects generated by a process. In other words, the total financial losses are defined in external and internal costs categories. Fig. 4 illustrates the outcome of the cost of quality and its significant impact on the organizations' profitability. To improve the process control and supplier quality control, quality control requires monitoring the key variables during production to eliminate the non-conformances downtime, scrap costs, and late shipment issues.

Collecting detailed design, manufacturing, or purchasing data and monitoring assets in the field for quality events serve as a guide to reducing the nonvalue-added costs toward service campaigns and warrant costs. Ultimately, the digital transformation solution enables the optimization of quality control by utilizing throughput enhancement, process improvement, and equipment downtime elimination [15].

PERFORMANCE MONITORING, PREDICTIVE QUALITY, AND MAINTENANCE MANAGEMENT

This section of the research provides some examples in the automotive industries where utilizing digitalization leads to resolving the challenges in quality management. The results for the case

studies in Table 2 are from Infor and Cloudera. The outcome of digital transformation in these examples illustrates the improvement in quality monitoring, real-time operational dashboard, predictive maintenance, quality event detection, and traceability by applying enhanced methodologies. Performance monitoring, predictive quality, and maintenance management are the main objectives of digital solutions for these challenges. Performance monitoring helps quality control while utilizing digital methodologies. In this approach, process tracking and observations are based on artificial solutions to monitor the key variables during production operation. Digital monitoring reduces the non-conformances, production downtime, and shipment delays while preventing the scrap costs and repair times during the processes.

Predictive quality and maintenance management are based on real-time and single-point access to critical quality information to prevent equipment downtime and maintenance costs. The real-time access to process data helps to increase collaboration and agility across business functions. The main objective of digitalization in this area is to reduce the non-value-added costs and scope of service campaigns by digitally tracing causes of failure to a specific design, manufacturing process, or supplier parts. In this methodology, the digital system collects history of manufacturing operation data to optimize the process variables by constantly monitoring the key variables during production [19].

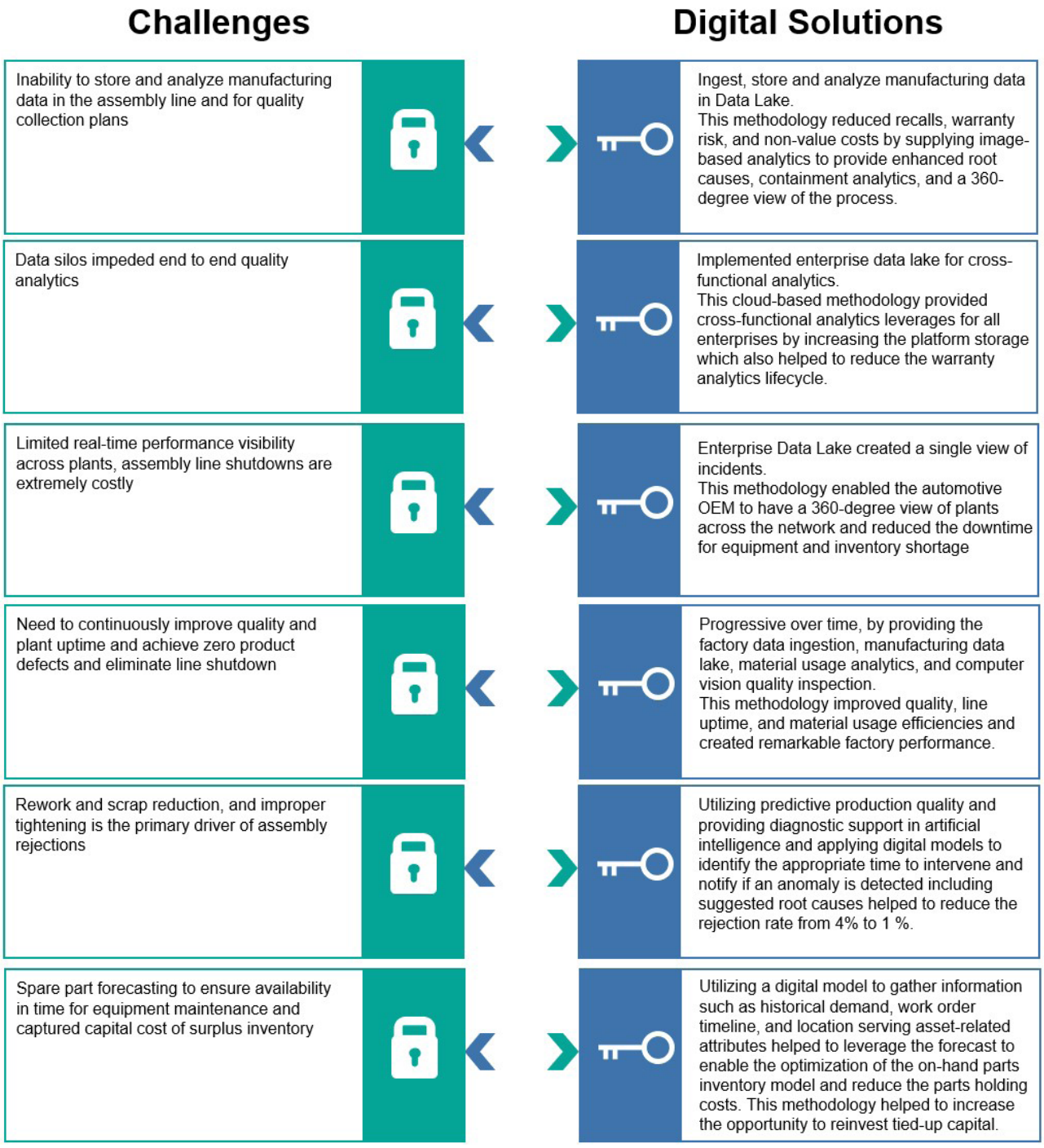
Overall, the digital solution in quality control provides the early detection for potential failure. The advanced methodology eliminates factory downtime through process improvements. Accessing a 360-degree view of processes enables agile collaboration, which can detect the root causes early in the process and prevents defect costs and delays in the system.

QUALITY INSPECTIONS (COMPUTER VISION)

The digitalization revolution evolves the full automation in smart manufacturing systems by utilizing machine vision. The computer-based monitoring delivers advanced capabilities to the processes that require lots of time and effort to screen the products and services. Computer Vision (CV) and automatic quality inspection are the most prominent and modern industrial technologies that can replace any repetitive and manual quality control process.

Machine vision is a field of artificial and advanced technology that concentrates on the digital images or sequences of images and videos to extract information. CV is a subcategory of digital transformation that analyzes and interprets the collected visual data utilizing digital systems such as cameras. The digital transformation that analyzes and interprets the collected visual data utilizing digital systems such as cameras. The digital system helps to classify acceptable vs. not acceptable outcomes by applying a trained algorithm to detect quality issues in real-time and autonomously. Implementation of computer visioned quality control improves the accuracy, effectivity, and productivity of the manufacturing system while eliminating the non-conformances, downtime, scrap costs, and non-value-added activities [19].

Table 2: Utilizing Digital Transformation in Quality Control Case Studies; *Source: Infor and Cloudera [19]*



CONCLUSION

Understanding the applicable framework of drivers of digital transformation and its impact on quality assurance is the main objective of this research. It is crucial to identify and analyze the drivers that stimulate the digital conversion in manufacturing processes, specifically in automotive industries. Based on the interviews conducted throughout the research, digital transformation involves profound changes in the business model of the organizations, which foster modifications in processes, resources, operational methodologies, and quality assurance standards.

The primary objective of quality assurance is to evaluate the entire activities in the processes and procedures of a system and improve quality, including training, documentation, monitoring, and audit. As customer demand and expectation increase, the digital transformation journey becomes critical for an organization to compete. The key challenge in this journey is to overcome the organization's acceptance of the new technology, integrating, transitioning, updating the old systems, and training the workforce. Implementing a reliable quality management system can overcome the current challenges in manufacturing organizations, such as excess documentation, supply chain complexity, lack of quality equipment, not enough implication and communication, lack of resources and time, and no training and development. Digital, advanced, and automated management system in quality utilizes a cloud-based methodology to coordinate the planning, team collaboration, monitoring, and delivery of the projects based on the digital data on a network of remote servers.

Advanced technologies and Industry 4.0 influence the perspective of quality management. Enhanced quality control techniques impact product design, end-user expectation, operational performance, and customer satisfaction. The examples and case studies of modern methodology showcase that digitization increases the opportunities for utilizing the application of advanced technologies while elevating cloud-based data gathering and expanding connectivity.

In general, automated systems and artificial intelligence will constantly provide an additional surge in the quality of products or the quality of life of end-users.

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