Agile Software Development in the Cloud Using Citizen Development

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The field of information and communication technology remains highly dynamic and continues to be prolific in the emergence of new and innovative paradigms, methods or concepts. In this context, we aim to highlight the evolution of the Citizen Development concept and the impact of Low-Code/No-Code (LCNC) platforms on business software development. These solutions democratize access to programming and allow users without formal technical knowledge to create agile software applications adaptable to various business scenarios. The progress of cloud computing, together with the need for rapid digital transformation and the increasing demand for software solutions, has accelerated the adoption of LCNC. However, the use of these platforms also involves challenges that may affect security, compliance with existing regulations, and the overall quality of applications. Thus, designing a hybrid collaboration model between software development teams and Citizen Development becomes essential for the successful implementation of applications created using these technologies. Despite the challenges, LCNC remains a suitable solution for innovation and digital transformation. The future may also rely on artificial intelligence integration, supporting agile development through intuitive interactions and enabling application creation via textual descriptions or even voice commands in natural language.

Keywords: *Agile software development, Cloud computing, Citizen development, Low-code, No-code*
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1 Introduction

In a world where digitalization is becoming a necessity, organizations are seeking fast, agile and efficient solutions to automate their processes and develop customized applications. In recent years, technology has evolved at an accelerated pace, and companies are facing a constant need for rapid and efficient digitalization [1]. According to a Gartner report, the global talent shortage is the primary emerging risk that organizations are confronting [2]. This factor, combined with the increasing demand for customized applications [3, 4] and the shortage of IT specialists [5, 6], has driven organizations to look for alternative solutions for software development [7]. Thus, Citizen Development (CD) has emerged and strengthened—a concept that allows non-technical employees to create applications through low-code and no-code (LCNC) platforms. CD has become a business practice in which a user - the so-called citizen application developer - creates/develops applications in the business software domain for use by others. This democratization of software development has become a cornerstone for companies that aim to accelerate innovation and reduce the time required to deliver digital solutions [8]. The citizen developer can be an employee of an organization (internal developer), from another organization (outsourced developer), or an independent contractor (freelancer – independent developer) – Figure 1.

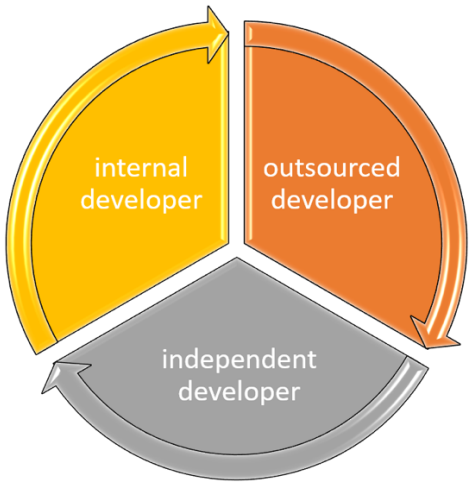

Fig. 1. The nature of the citizen developer

However, the success of CD would not have been possible without advancements in Cloud Computing (CC). Cloud platforms have provided the necessary technological foundation for non-technical users to develop and deploy applications without requiring complex IT infrastructures. The scalability, accessibility, and security offered by the cloud have enabled companies to manage their resources more efficiently and support internal developers in creating innovative solutions [9].

Several factors have contributed to the rapid rise of these two concepts. The COVID-19 pandemic forced organizations to adopt digital solutions within a short time frame to maintain and reorganize operational activities. At the same time, the previously mentioned IT talent shortage overwhelmed technology departments with development requests. Finally, the maturation of LCNC technologies has also played a role in this phenomenon, making them easier to use while providing more functionalities. Their evolution has allowed employees without technical experience to create complex applications [10]. Additionally, the widespread adoption of the cloud has provided the necessary infrastructure for hosting them [11].

Thus, CD and CC have become important pillars in the digital transformation process, holding the power to redefine the way organizations develop and implement technological solutions. To fully understand the impact of LCNC platforms on the software industry and the digitalization process, it is important to analyse both the advantages and the challenges they entail. Although LCNC offers a high degree of accessibility and reduces development time and costs, there are also concerns related to security, scalability, and the technological limitations of these solutions. In addition, the integration of artificial intelligence (AI) into these platforms opens up new opportunities, but also introduces challenges in terms of democratizing software development. Therefore, this research aims to answer the following questions:

1. How do CD and LCNC platforms influence the process of digitalization and innovation in organizations?
2. To what extent have LCNC platforms contributed to the democratization of software development and the reduction of dependence on IT teams?
3. How has the transition to CC impacted the adoption and evolution of LCNC platforms within organizations?
4. What are the key factors that have driven the accelerated adoption of LCNC platforms, and how have they influenced organizations' digital strategies?
5. What are the main challenges and limitations of adopting LCNC platforms, and how can they be managed to ensure application security and scalability?
6. How will the integration of AI influence the evolution of LCNC platforms, and what impact will it have on the democratization of software development?
7. The sections of this paper are structured so that each of them directly addresses the formulated questions. Thus, Section 3 addresses Questions 1 and 2, Section 4 answers Question 3, Section 5 focuses on Question 4, Section 6 addresses Question 5, and Section 7 provides answers to Question 6.

2 Research Methodology

In this research, we adopted a mixed approach that combines both qualitative and quantitative research to obtain a more detailed understanding of the impact of LCNC platforms on the application development process, especially in the context of adoption by non-technical users and their integration into organizations. The main goal of this research is to examine the evolution of LCNC platforms under the cloud computing umbrella and to understand their impact on organizations. The research aims to answer the six questions mentioned above. These target both the development of LCNC platforms and their benefits and limitations they provide for businesses. To have the broadest outlook, the chosen methodology consists of a detailed review of the existing literature. Academic articles, industry reports and case studies were included. Through this analysis, we have identified the

most important trends and advances in the field. The main objectives of the research are:

- Analysing the impact of LCNC platforms on the development process of agile software applications specific to various industries.
- Evaluating the adoption rate of these platforms in organizations and identifying the main benefits and challenges.
- Study of concrete cases from different industries, such as education, the automotive sector, and others, to observe the applicability and efficiency of LCNC platform.
- This review will allow for answering the research questions. The results will provide a detailed understanding of the evolution of LCNC platforms within the cloud architecture. Furthermore, the research will explore the future perspectives of these platforms in the context of organizational digitization.

3 Evolution of Citizen Development

Before the emergence of CD, the concept of *Shadow IT* had spread considerably within organizations. This phenomenon is characterized by employees using external technologies and applications without the approval or oversight of the IT department. One possible explanation for this behaviour lies in the frustration caused by the slow pace of official technology implementation and the limitations imposed by IT departments. Although Shadow IT allowed for rapid innovation, it also generated significant risks, such as security vulnerabilities and compliance issues [12]. In this context, CD evolved as a solution based on methods and frameworks supported by IT, which enables non-IT users to develop applications using LCNC platforms. This eliminates the risks associated with Shadow IT and promotes a more efficient and secure agile software development. CD is a model that encourages individuals without formal IT training to create software applications through intuitive visual interfaces such as drag-and-drop functionalities and modular components. As a result, the need for manual coding is reduced. This approach provides companies with greater flexibility and reduces dependence on IT teams.

The concept of CD has been significantly analysed and defined since 2012 in a report published by Gartner, titled "*Citizen Development: Reinventing the Shadows of IT*" [13]. This study examines the rising phenomenon of software developers without formal IT qualifications and highlights the fact that they began creating their own applications due to the technological advancements of LCNC platforms. The author claims that this phenomenon should not be perceived as a threat to IT departments, but rather as an opportunity for collaboration and streamlining the digitalization process. It also underlines the need for organizations to provide adequate support and infrastructure for CD so that the solutions created are not only innovative but also secure and scalable.

A more recent analysis, conducted by Bukhari et al. [14], complements the theoretical foundations of CD by examining aspects related to benefits, governance, organizational maturity, and the challenges of implementing this concept. The authors reason that CD has the potential to significantly reduce pressure on IT teams while allowing non-technical employees to develop their digital skills. At the same time, it highlights challenges related to data security, application interoperability, and the need for a strict governance framework to avoid the creation of fragmented and unsustainable solutions in the long term.

Major players in the low-code platform domain, such as Microsoft Power Apps, Google AppSheet, and OutSystems, play an important role in accelerating organizational digitalization by simplifying and speeding up the application development process. The fierce competition between these major players for market share since the early days of the technologies has generated significant competition. This results in a major benefit for users, as the solutions offered are becoming increasingly innovative and accessible. Specifically, Microsoft Power Apps allows users to create applications for automating internal processes using visual elements. Google AppSheet uses data from Google Sheets to develop

applications based on it. On the other hand, OutSystems stands out due to its ability to develop more complex web and mobile applications that have high scalability and various integration capabilities with other systems. Often used in industries where application complexity is high, such as the financial and telecommunications sectors, the company enables organizations to implement customized solutions without compromising security and performance. These platforms, with their intuitive interfaces and predominantly visual operating modes, make application development accessible to a wide range of users from various fields.

In this context, a relevant example of the application of the CD concept is the use of Microsoft Power Apps at a university for the development of customized educational applications aimed at training residents in pathology, which were launched through Microsoft Teams [15]. These applications were developed using a low-code approach, which enabled rapid integration into existing workflows and efficient customization of the educational process, improving the continuity of distance learning during the COVID-19 pandemic. According to the research conducted, the applications were appreciated by residents and professors, enhancing learning, exams, and file sharing in a single platform accessible to all users within the university.

The adoption of low-code applications is not limited to the educational sector. It also extends into other industries, where customized solutions are increasingly used to modernise processes. A relevant example is the development of an application for managing hazardous materials using Microsoft Power Apps. It aims at eliminating the use of paper and to improve quick access to important information, such as safety data sheets and the expiration dates of materials [16]. Additionally, the integration of deep learning algorithms into Microsoft Power Automate workflows has allowed the automation of processes, with prominent applications in areas such as predictive maintenance for machinery used in production, customer sentiment analysis in retail, and fraud detection in financial services [17].

In the educational domain, another important example is the use of Microsoft Power BI for visualizing graduate data during the COVID-19 pandemic [18]. The reports allowed the university's leadership to quickly understand the information. In the automotive industry in Malaysia, an application developed using Google Sheets and AppSheet led to significant improvements in the order management process [19]. It also reduced errors and the time required to process orders within an automotive supplier's supply chain. These examples not only highlight the versatility of low-code platforms, but also reveal their impact on process efficiency across various sectors.

4 Cloud Computing and Its Impact on CD in Agile Software Development

The concept of cloud computing was outlined as early as the 1960s but began to gain popularity at the beginning of the 21st century. It quickly became an important pillar in the development of digital infrastructure. The transition to the cloud allowed companies to access scalable and flexible computing resources without making massive investments in on-premise infrastructure [20]. Currently, cloud services are structured into three main categories: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Each of them has a significant impact on application development. For CD, these services represented a turning point. SaaS offers users immediate access to fully functional software applications and eliminates the need for custom development for basic functionalities. This helps companies to avoid significant upfront costs [21]. In this way, they benefit from the flexibility to rapidly scale applications according to their operational needs and eliminate the risks associated with over- or under-provisioning IT infrastructure. PaaS, on the other hand, allows for the creation of applications using pre-configured development environments, such as Mendix and Salesforce [22]. Meanwhile, IaaS provides organizations with scalable infrastructure, allowing applications to be developed and run without the limitations imposed

by local resources.

With the increase number of applications developed by non-technical users, data security and infrastructure scalability have once become major concerns. Initially, the migration to the cloud was met with scepticism due to the risks associated with protecting sensitive information [23]. However, cloud providers have implemented advanced security solutions, such as multi-factor authentication (MFA) [24], data encryption [25], and compliance with international standards (GDPR, ISO/IEC 27001, SOC 2) [26, 27, 28]. These measures have strengthened organizations' trust in cloud services and accelerated the widespread adoption of CD solutions. The trend has also been supported by the development and expansion of fog computing paradigms and, in particular, edge computing. Table 1 compares Cloud, Fog, and Edge computing in terms of security, accessibility, latency, and scalability, highlighting their key differences and applications.

Table 1 - Comparative analysis of cloud, fog, and edge computing (Sources: [20, 29])

Characteristics	Cloud Computing	Fog Computing	Edge Computing
Definition	Infrastructure based on remote servers that offers services and storage over the internet.	Provides services between the cloud and end devices, processing data at the network's middle layer.	Computing is done directly on or near the end devices.
Security	Depends on the cloud provider but can be vulnerable to DDoS attacks and unauthorized access to sensitive data.	More distributed but still exposed to network risks. It may offer greater control over sensitive data.	Greater security at the local device level, but risks are related to managing end-user devices.
Accessibility	Highly accessible globally, usable via the internet, but can be influenced by network latency and internet availability.	More accessible than pure cloud, offering resources between cloud and local devices but less than Edge.	Near-instant accessibility, as processing is done directly on end devices.
Latency	Higher latency due to data processing from a distance.	Lower latency than the cloud due to processing closer to local networks.	Very low latency, almost real-time, as processing happens directly on end devices.
Scalability	Extremely scalable, as cloud resources can be adjusted quickly based on demand.	More limited scalability than cloud but flexible in distributed networks.	Scalability limited to the capabilities of local devices.
Costs	Variable costs, but can increase as data volume processed grows.	Lower costs than cloud due to partial processing, but higher than Edge due to infrastructure complexity.	Lower costs as processing happens locally without relying on external servers.
Performance	Performance dependent on internet connection and cloud servers.	Better performance than cloud in certain cases, due to processing being closer to the user.	Excellent performance for real-time applications, as data is processed locally on end devices.
Network Dependency	Highly dependent on a stable internet connection.	Less dependent on the network than the cloud, but still requires a connection to access the cloud.	Minimal network dependency, as most processing is done locally.
Applicability	Used for applications requiring high resources and not sensitive to latency (e.g., data storage, data analysis).	Used for applications requiring rapid processing that cannot be fully managed on end devices (e.g., smart cities, autonomous vehicles).	Ideal for applications requiring real-time processing with low latency (e.g., IoT, autonomous vehicles).
Example Use Case	Data storage on platforms like AWS, Google Cloud, etc.	Data analysis collected from sensors in a smart city.	Data processing directly on IoT devices or mobile phones (e.g., health apps).

In addition to security, scalability is another important benefit when developing

applications in the cloud. Cloud platform configuration portals permit automatic adjustment of resources allocated to applications based on user demand. For example, if an application reaches a critical usage threshold, resources such as processing capacity and storage are automatically allocated. This helps maintain optimal performance levels without the manual intervention of personnel. As a result, the risk of application downtime is reduced, and costs are optimized [30].

In conjunction with these measures, security solutions, such as antivirus, custom policies, firewalls, and virtual private networks (VPNs), are also available. They protect applications and data from unauthorized access. These services help safeguard infrastructure against external attacks. Furthermore, solutions for secure data storage, recovery, and replication are also provided. These minimize the negative effects of successful cyberattacks and allow organizations to continue their operations. They represent solutions for the most common types of attacks, such as ransomware and DDoS, whose incidence is continuously increasing [31].

LCNC development platforms are mostly cloud-based and are offered as web applications, allowing users to access them directly from a browser without the need to install additional applications on their devices. These platforms host the created applications, thus eliminating the need to implement and manage IT infrastructure. This is a noteworthy benefit of LCNC technologies, which contributes to their extensive adoption, especially among users without experience in software development. While there are also LCNC solutions that are not cloud-based and are installed in on-premise infrastructure, cloud platforms represent a much more accessible and scalable option, suitable for most organizations looking to simplify and accelerate their application development process [32].

Flexibility is another important factor to consider. The cloud allows applications created on LCNC platforms to be accessed from any device [33]. Additionally, many of these platforms integrate with advanced cloud services (such as APIs, managed databases, or data analytics services). These integrations enable companies to add complex functionalities, such as querying external systems. The integration of AI and machine learning (ML) technologies are other key elements that have become possible in recent years with the evolution of LCNC platforms [34]. As a result, new and advanced functionalities for sentiment analysis, natural language processing (NLP), and object recognition are now available directly in drag-and-drop visual interfaces, without requiring any code writing [35, 36]. Furthermore, users can take advantage of ML algorithms to analyse data, including linear regression, root cause classification, and other clustering techniques [37, 38].

5 Factors that accelerated the adoption of LCNC platforms

The adoption of LCNC platforms has been accelerated by several factors that created optimal conditions for rapid technological modernization. Among these factors are the impact of the COVID-19 pandemic, the IT specialist shortage, the improvement of LCNC technologies, and the changes made to the IT policies and standards of large companies.

The pandemic generated an urgent need for digitalization across all industries, prompting companies to rapidly adopt efficient technical solutions to maintain their operations. In a context where employees were forced to work remotely and physical interaction was limited, LCNC platforms became essential tools capable of handling the sudden increase in software demand. They contributed to the rapid implementation of software solutions to support workflows and automate processes. At the same time, they supported the efficiency of communication without the need for dedicated software development teams. This way, companies were able to implement digital solutions quickly and reduce their dependency on traditional software development [39, 40, 41, 42, 43].

Although the current IT crisis has shifted from a shortage of specialists to a situation where they face difficulties in finding jobs [44], during the pandemic, there was a similar crisis, characterized by a significant lack of

professionals in this sector, compared to market needs. The IT industry no longer faces an acute shortage of specialists, but this was a significant reality in the past. It contributed to the expansion of LCNC platforms as a solution to address this deficiency [5, 6]. The growing demand for digital solutions, combined with the limited number of available developers, led companies to adopt more accessible and faster alternatives for software development. LCNC platforms responded to the need for rapid development during that time, and although that crisis has been overcome, the applications developed through them continue to be used and have not been replaced by solutions created by specialized programmers. With technological advancements, LCNC platforms have significantly evolved, becoming increasingly complex and capable of addressing the diverse needs of companies [10]. Today, they integrate advanced features such as process automation, AI, and ML [34], connectivity with external APIs, and high scalability. This growth of LCNC technologies has transformed these platforms into viable alternatives for developing complex applications, prompting companies to adopt them at an accelerated pace. The adoption of LCNC platforms has also been influenced by changes in the IT regulations and policies of large companies. More and more organizations have started to encourage the use of these platforms as alternative solutions for developing new functionalities [10]. In this way, they have reduced the time and costs associated with traditional software development.

LCNC platforms offer a significant financial advantage for organizations. Developing applications through these platforms sustains lower costs compared to traditional software development, which relies on specialized software development teams. In this way, companies avoid significant expenses associated with recruiting and maintaining large technical teams, and the development time is reduced. Both factors also contribute to better financial resource management. Additionally, the maintenance and update costs for applications built through LCNC are lower due to their flexible and scalable nature. Thus, organizations can allocate the saved resources to other strategic projects. Efficiency is thus increased, and the pressure on IT development budgets is reduced [45].

The evolution of LCNC platforms has led to their general adoption, despite initial technological and organizational barriers. These solutions have become feasible alternatives for developing complex applications, supported by changes in the IT policies of large companies. Another important factor in the growing adoption of LCNC is the financial advantage they offer by reducing the costs of development, maintenance, and updating applications, thus contributing to more efficient management of organizational resources.

6 Challenges and Limitations of LCNC Platforms

While there are many benefits to using LCNC systems, there are also several drawbacks and restrictions that need to be considered. These include risks related to security, compliance, and the quality of applications developed without advanced technical expertise. Therefore, a balance is needed between traditional software development and CD involvement. The adoption of these solutions is hindered by multiple barriers, which go beyond the perception that LCNC platforms are suitable only for simple applications. A study based on semi-structured interviews [46] identified 19 inhibitors of LCNC platform adoption, divided into five categories: environment, human factor, structure, tasks, and technology. Among these, most obstacles fall into the technological category, but organizational and user-related factors also influence the adoption of these platforms.

Security remains one of the main concerns in the use of LCNC platforms, especially those based on web technologies. A study by Oltrogge et al. [47] highlights important vulnerabilities in the security mechanisms of several tested application generators, particularly regarding SSL certificate management, protection of interactions between components, and prevention of cyberattacks. This issue is further aggravated by the fact that many LCNC applications are developed by

individuals without professional training in the field. Unlike experienced software developers, these users are not familiar with security risks. This lack of technical knowledge can lead to the implementation of solutions with serious flaws, making them potential targets for attackers. The absence of verification mechanisms by IT teams can introduce vulnerabilities into an organization's infrastructure through applications developed using LCNC technologies.

While LCNC platforms provide a fast and accessible way to develop applications, they have limitations compared to traditional software development. According to Shridhar et al. [48], traditional development allows for unlimited customization. It permits unrestricted customisation, allowing businesses to combine preferred solutions and provide any necessary functionality. In contrast, LCNC platforms are often limited to predefined functionalities and modules provided by the vendor. Furthermore, although LCNC simplifies the development process through visual interfaces and automation, it limits control over the architecture, security, and compatibility of applications. Traditional development, on the other hand, grants companies full control over source code and the implementation of advanced security measures. Another major difference lies in technological flexibility: LCNC requires the use of its own platforms, whereas traditional development allows developers to choose any programming language or hosting infrastructure [49]. Thus, for complex projects that require a high degree of scalability and advanced business logic, traditional development remains superior.

The autonomy granted to CD raises the challenge of maintaining a balance between user-led development and IT specialist involvement. If inexperienced users work without guidance, there is a risk of creating applications that do not comply with organizational architecture and standards. Furthermore, LCNC-based solutions may face long-term maintenance and scalability issues. For this reason, a collaborative framework between IT teams and business users is necessary, establishing best practices, usage guidelines, testing mechanisms, and validation processes to confirm that developed applications are properly integrated into the company's technological ecosystem while meeting security, performance, and scalability requirements.

7 Technological and Practical Perspectives

The rapid evolution of LCNC platforms indicates a promising future for these technologies, especially through the increasingly advanced integration of AI. As organizations accelerate their digital transformation, LCNC is becoming an essential part, because it eases the access to software development for a wider range of users. These platforms are not only designed for software developers but also to a diverse audience of users, including children, students, entrepreneurs, professionals from various fields, and individuals with minimal technical experience. They offer the opportunity to create applications without requiring advanced programming knowledge. In this context, three major development directions are emerging: intelligent automation, the amplification of AI usage, and the global rise in popularity of these technologies.

The integration of AI into LCNC platforms will redefine the concept of CD by providing non-technical users with access to advanced functionalities. Automated Machine Learning (AutoML) and pre-built AI models will allow for the creation and deployment of applications with minimal effort. As a result, these platforms will become more intuitive and capable of automatically suggesting improvements to optimize workflows and reduce reliance on IT teams. Furthermore, by combining LCNC with Robotic Process Automation (RPA) and Business Intelligence (BI), organizations will be able to adopt hyper-automation, eliminating redundant manual processes and increasing business efficiency [50, 51]. In the future, we predict that drag-and-drop functionalities and other visual interfaces will be replaced by natural language-based interactions. Users will be able to describe their desired outcome in their own words, and AI-powered platforms will interpret these requirements and build the corresponding applications. This shift will ultimately lead to the

near-complete elimination of manual intervention in the development process.
In the medium and long term, AI will become the core of no-code development, providing predictive and adaptable solutions. No-code AI democratizes the use of artificial intelligence by enabling even non-technical users to create and deploy machine learning models. This phenomenon will diversify the approach to AI adoption, fostering interdisciplinary collaboration and reducing costs associated with hiring data analysis specialists. Furthermore, AI will improve security and compliance within LCNC through automated auditing and governance mechanisms, ensuring transparency and regulatory adherence [52, 53].
The global adoption of LCNC platforms is continuously expanding, and current trends suggest significant growth in the coming years [54]. This progress is backed by elements including high accessibility, reduced development time, and the increasing need for organizations to become more agile in implementing digital solutions. An emerging trend is the integration of LCNC with technologies such as Edge AI and IoT, enabling real-time data processing on personal devices without relying on cloud infrastructure. At the same time, the development of AI models that adhere to ethical and security standards will help build trust in these technologies. In this context, LCNC platforms be a major factor in shaping the future of software development, offering scalable and accessible solutions worldwide [50].

8 Conclusions

The evolution of LCNC platforms has demonstrated significant progress in democratizing software development and allowed users without technical experience to create software applications for organizations. These technologies have reduced development time and costs while maintaining a high degree of accessibility and flexibility. However, extensive adoption has also highlighted challenges related to security, compliance, and the quality of developed applications.
An important factor contributing to the success of LCNC is the implementation of a hybrid model between IT teams and CD. These platforms should not replace traditional developers but rather support collaboration. In this way, IT teams can establish security and infrastructure rules, while non-technical users contribute to the development of functionalities. By doing so, a proper balance between agility and control will be upheld while mitigating the risks associated with uncontrolled development. In addition, integrating quality assurance (QA) processes throughout the entire agile software development lifecycle is essential for maintaining performance and reliability standards of applications created in the cloud context using CD.
For entities that wish to implement these technologies, it is recommended to establish a governance strategy. This strategy should include security and compliance policies for developed applications. Moreover, non-technical users should receive training on software development best practices and security. LCNC solutions should also be integrated with traditional IT systems. Additionally, continuous monitoring and optimization of applications are necessary to prevent the accumulation of redundant or inefficient solutions. By following these recommendations, organizations can fully leverage the advantages of LCNC platforms while maintaining a secure and efficient software ecosystem.

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