

Review Article

The Transformative Impact of Container Technology in Public Sector Organizations

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Abstract

The introduction of container technologies in the public sector has significantly driven the digital transformation. IT departments have recognized the importance of this new innovative and highly efficient technology and identified these insights as key to improving existing processes and systems. This has increased the IT landscape's ability to innovate and overcome the challenges of IT infrastructure efficiency, scalability, security and rapid application deployment. This article examines in detail the adoption and impact of container technology in public organizations. The numerous benefits such as increased efficiency, scalability and flexibility as well as the existing challenges in terms of integration, security and regulation are highlighted. In addition, future potential of this technology is also shown. A comprehensive analysis of existing research shows that the use of container technology for digital transformation in public organizations leads to greater organizational flexibility, delivery efficiency, resource utilization transparency, and IT infrastructure security. This article provides an analysis of the existing challenges and successes of public organizations. It also assesses the potential and highlights possible obstacles for the public sector and emerging trends. The results of this study demonstrate that container technologies have significant potential in terms of innovation, flexibility, efficiency and security for public organizations. These findings form a solid basis for further research activities in this area.

Keywords

Public Organization, IT Operation, Container Technology, Resource Optimization, Application Development, System Resilience, Regulatory Compliance

1. Introduction

Container technologies have become a crucial success factor for the digital transformation strategy in the public sector. This technology is primarily used to simplify and accelerate the deployment of applications, make the use and management of resources more efficient and transparent, and increase the security and stability of IT infrastructure. Containers are software packages organized to include all elements (code, runtime, configuration, and system libraries) necessary to run the soft-

ware. In this way, containers virtualize the operating system, are independent, and can therefore run anywhere and in isolation. In the public sector, this technology plays an important role as it significantly improves the effectiveness, efficiency, and security of public services for citizens. This article focuses on the introduction, use, and potential of this technology in public organizations. It highlights the benefits, existing challenges, and opportunities of this innovative technology for the

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public sector. Additionally, it examines specific challenges related to regulatory compliance and the complexity of the IT landscape in the public sector.

Recent studies show that container technologies are increasingly being used in the public sector to make IT infrastructure more efficient [1]. Research has emphasized that container technologies improve the scalability and security of IT environments, which is crucial for the efficient deployment and operation of applications in public organizations [1]. Case studies from various public organizations have shown that container technologies can improve operational efficiency and resource management [2]. Additionally, it was analyzed how the integration of container technologies with digital twins in seaports can improve the monitoring and management of complex IT systems [3]. The study emphasizes the importance of container technologies for flexible, secure, and adaptable IT landscapes, which are indispensable for the digital transformation of public organizations [1, 2].

The analysis is based on results and insights from current research and case studies. Many organizations, especially in the public sector, have a complex IT landscape composed of current and legacy technologies. However, this IT landscape needs to become flexible, secure, and easily adaptable. The introduction of container technologies helps to achieve the stability, scalability, and security of IT environments to optimally develop, deploy, and operate applications. Furthermore, container technologies offer a high degree of portability compared to traditional virtualization methods, enabling organizations to scale their operations flexibly and as needed. Additionally, this technology promotes organizational excellence by providing methods such as logging, monitoring, and user management.

Despite the many advantages this technology brings, public organizations face significant challenges related to regulatory compliance, integration into existing systems, and a lack of expertise. Moreover, driving factors such as flexibility, efficiency, security, and growth in an ever-changing digital environment make IT departments sought-after catalysts for digital transformation. With the right strategy, tools, and expertise, IT departments in public organizations can leverage container technologies to foster and advance innovation and digital transformation. This can, in turn, lead to productivity gains and cost savings.

2. Methodology

Search Strategy

There is a large amount of literature on the topic of container technology in general. The literature search on the transformative impact of Container Technology in Public Organizations was carried out across multiple databases, including ScienceDirect, IEEE Xplore, ACM Digital Library, PubMed, and Google Scholar. Relevant articles were found using keywords like cloud computing, virtualization, IT strategy, Docker, Kubernetes, container, container technology, public sector, and government organizations. Additionally, the

search was restricted to articles after January 2022 to ensure the inclusion of the most recent and relevant studies.

Inclusion and Exclusion Criteria

To ensure the relevance and accuracy of the data, as well as to maintain the integrity and reliability of the information, certain characteristics had to be included or excluded.

Criteria for Inclusion: The criteria for inclusion are as follows: works or papers published in English, academic papers published from January 2022 onwards, academic papers with a strong focus on the use of container technology in the public sector, academic papers that provide insight into the benefits and challenges of container technology in public sector organizations, and publications from reputable academic journals, conference papers, and peer-reviewed literature.

Criteria for Exclusion: Exclusion criteria include sources that are not peer-reviewed or lack an academic foundation, such as news articles, blogs, and opinion pieces; sources that are not fully accessible; and any publications dated before January 2022.

Data Extraction and Analysis

The following search terms Container Technology, Container Platform, Virtualization, Ecosystem, Application Development, Scalability, Security, Digital Transformation, Public Organization, IT Operation, Operating System, Production Environment, Resource Optimization, System Resilience, and Regulatory Compliance were used and combined in various ways for analysis. First, irrelevant results or obviously not suitable for the topic were then set aside to maintain consistency and applicability of the collected information. In the next step, a standardized qualitative form was used to extract the necessary data, which included the following elements:

1. Date of publication, authors, and title.
2. Research questions and goals.
3. Issues and limitations.
4. Findings.
5. Significance and relevance to the topic.

Quality Assessment

To evaluate the quality of the included studies, criteria such as the reliability of the findings, and their relevance to the review's goals were used. Studies deemed to be of high quality were given greater emphasis in the synthesis of the literature.

Criteria	Description
Date of Publication	Relevance of the information to recent advancements in the field
Relevance and significance to Review Objectives	Alignment with review objectives and contribution to the existing knowledge
Main Findings	Summary of the work's main results and implications

Figure 1. Quality Assessment Criteria (Source: Own Representation).

3. Literature Review

Historical Context

Over the past few years, container technology has transformed significantly, expanding its use from niche markets to the public. In contrast to the private sector, which quickly adopted container technology to increase efficiency and scalability, the public sector has been slower to react due to security concerns and regulatory requirements. Container-based solutions create a unified and stable environment for developing, testing, and deploying applications, thereby significantly reducing deployment time. They are replacing traditional virtualization techniques in IT infrastructure to improve cost-effectiveness and flexibility [4, 5].

The foundation of container technology is based on the concept of combining and thus isolating all dependencies of an application in a single, independent area called a virtual container, thereby increasing the portability of applications. The application's libraries, setup files, and binaries are all included in this encapsulation, which ensures that they will run consistently in any environment. This isolation ensures that applications work consistently regardless of the underlying hardware or operating system. When compared to traditional virtual machines, containers are more efficient and can start up more quickly. This is because they use the base of the host operating system and are naturally lightweight. The use of this technology has enhanced the deployment of applications in a more efficient and reliable way through its focus on portability, scalability, and isolation [6, 4].

The modern era of container technology started in 2008 with the so-called release of Linux Containers (LXC), which separated applications into namespaces and groups. The year 2013 witnessed a breakthrough in container technology with the release of Docker – a platform with various components that abstract some of the tedious tasks that users would otherwise have to deal with in the low-level virtualization of operating systems, this innovation made it simpler to bundle applications with their dependencies by providing a framework for building, deploying, and managing containers [7-9].

Container management systems such as Kubernetes have now emerged as the standard platform for large-scale automating deployments. The objectives of both container technologies and conventional virtualization techniques are efficient utilization of resources and program execution. However, these objectives are pursued through distinct approaches. Conventional virtualization involves the operation of multiple operating systems (OSs) on separate virtual machines (VMs) on a single physical computer. Containers are designed to be diminutive and expeditious, leveraging the base operating system and constrained execution within user-defined domains. According to extant studies, containers utilize less system resources and initiate and terminate faster than virtual machines. This capability, or so-called feature, is highly beneficial for microservices as well as cloud-native initiatives. Even though current container-based technologies offer better

isolation and security, the shared kernel in containers might still pose a security threat [8].

Theoretical Frameworks

In recent research, various theoretical models have been used to address the challenges of container orchestration, specifically container management, organization and security, including the following one:

1. Orchestration through machine learning can improve container orchestration. These models use probability-based, knowledge-based and evidence-based data fusion algorithms to effectively address data challenges using core components such as model selection, generation, optimization, evaluation, deployment, testing and data collection in model development. Based on this, deployment plans can be optimized, scaled and automated [9].
2. Security frameworks depend on the specific requirements and context of organizations' IT landscape and thus influence the use of container technologies. The main purpose of security frameworks is to provide guidelines and recommendations for dealing with security concerns and challenges related to container technologies during the planning, implementation and maintenance of the container stack. In addition, security frameworks should optimally support mechanisms for rapid detection, optimal monitoring and isolation of threats [10].
3. Digital twin models are executable, simulation-enabled virtual models of physical systems that improve system performance and enable timely analysis of large amounts of data using real-time data from intelligent sensors. These models also help to predict system performance, adapt system behavior and accelerate decision-making processes by exploring different use cases and quickly evaluating expected outcomes under different operating conditions. These models have been successfully used in logistics and value chain management [6].
4. Cloud-native frameworks such as Kubernetes for the management of containerized applications has been the subject of a significant amount of research. These frameworks make it easier for application containers to be installed, scaled, and run automatically across host groups. In recent years, the focus has shifted from the theoretical study of Kubernetes to its practical application. These models also make it possible to minimize risk by transforming large applications into smaller, distributed systems while addressing key cloud issues [11].

These models show how several strategies might be used to deal with the difficulties and complications that come with container technology.

Containerization

Containerization represents a comprehensive concept of procedures, methods, and tools that enable the efficient deployment and management of software applications. In this

process, software code is isolated and packaged with only the necessary operating system libraries and dependencies required for execution, allowing it to run uniformly and consistently in various environments as a lightweight executable file, also known as a container. In contrast, virtual machines (VMs) enable the concurrent operation of multiple operating systems on a single physical machine. Containerization improves and accelerates the software development process, offering higher portability and efficiency, thereby saving resources [4].

Docker is a platform with various components, such as Docker Engine, Docker Images, Docker Containers, Docker Hub, Docker Compose, Docker Swarm and Docker Registry, that abstract some of the tedious tasks that users would otherwise have to deal with in low-level operating system virtualization. In other words, Docker lets you separate your applications from your infrastructure to quickly deploy software [12]. Docker containers exhibit a low memory consumption during their creation. A virtual machine (VM) generally necessitates at least 512 megabytes (MB) of disk space, whereas a Docker container can be created for a mere few kilobytes [13]. There is a separation between the "client" and the "daemon". The core component of the Docker platform is called the Docker Engine, which is completely open source and consists of three distinct parts: The Docker Daemon, a core service that manages Docker containers; the REST API, an intermediate layer responsible for interacting with the Docker Daemon; and the Docker Client (CLI), an interface layer that users interact with.

Adoption of Container Technology in Public Organizations

Container technology is used by many IT departments in public sector organizations to deploy and handle their applications because it has so many benefits. Datadog shows that the number of businesses using serverless containers grew from 31% in 2021 to 46% in 2023 (see Data Availability Statement). This implies increasing usage of it among people. This trend indicates that companies are growingly fond of container technology. Businesses are applying it to save running costs and boost the innovation rate in their goods and services [14, 15]. Many companies used containerized applications in some degree of their manufacturing processes and operations, and in different capacities generally [14-16].

Container technology supports fast pipelines between infrastructure and application platforms (e.g., DevOps pipelines), so public sector companies are increasingly relying on it for their digital transformation. According to Usman in 2024 [17], container technologies are quite important for meeting the growing demand for digital services. Strong security and automation are, according to the Hype Cycle for Container Technology, essential for maintaining robust container operations 2024 [17].

Case Studies and Examples

The application of container-based technology has let public sector organizations improve their operations.

1. Electronic government services: One among the most

important uses of container technology are electronic government services. Container availability and excellent performance make them indispensable for e-government systems to be scalable and strong [18]. One such is the GDS, or UK Government Digital Service. Docker was crucial for the introduction and operation of its digital service platform. The result of implementing a container update in 2024 at the application level of a U.S. federal agency was faster deployments and better scalability, leading to more efficient management of existing applications [17]. Another case study from 2024 [17] reports that an enterprise-wide container adoption significantly increased developer productivity through faster application deployments and improved resource utilization [17, 15].

2. Healthcare systems may also benefit from containers when it comes to managing and scaling applications, which enhances service delivery and patient data management [19, 20]. Container-based technology is used to ensure the availability of services by allowing rapid, secure, and stable rollouts. In the United Kingdom, the National Health Service (NHS) has embraced container technology to promote the acceptance of health applications. This project ensures the adaptability and scalability of health services by accelerating their delivery and improving patient care, thereby guaranteeing their availability [20, 21].
3. Public institutions are increasingly utilizing container technology to implement smart city applications for real-time data processing and analysis pertaining to urban management [22, 23]. This allows large amounts of data to be processed and analyzed efficiently. For example, Barcelona uses container technology to advance its smart city initiatives and enhance the necessary efficiency and flexibility of its urban applications. Furthermore, Barcelona improved waste management and traffic control efficiency by containerizing its applications, maximizing resource use and citizen satisfaction [24, 25].
4. Educational institutions: It has been found that container technologies can improve the organization of work in educational institutions as well as the interactivity and communication among participants. Container technologies offer efficient development and deployment of teaching materials and, due to their ability to be quickly and easily created, modified, and removed, enable the rapid distribution and use of container-based applications. During the pandemic, the University of Chicago used container technology and Amazon Elastic Kubernetes Service (Amazon EKS) for efficient and innovative data analysis and management in biomedical research [26]. At Harvard University, Docker containers and GitHub Codespaces were used to simplify and standardize the development environments of computer science students. The application of teaching concepts in

a lightweight virtual environment allowed instructors to focus more on delivering educational content [27].

5. In public transportation systems, Containers allow public transportation systems to manage and examine real-time data, therefore improving service quality and efficiency. Containerized applications allow cities to track traffic, adjust public transit routes, and notify drivers in real time [14]. The introduction of smart container ports in Shanghai and Rotterdam demonstrates how big data, IoT, and AI can improve logistics and transportation [28]. The integration of container technology into smart ports facilitates the optimization of logistical flow and the automation of port operations, thereby enhancing efficiency and reducing shipping expenses [6].

Public sector companies that have successfully implemented container-based technology have made remarkable progress in the stability and efficiency of many different sectors of the IT landscape, as well as in the quality of existing services. As public entities prioritize digital transformation, container technology will increasingly play a key role in building adaptable and robust infrastructures.

Challenges, Benefits and Opportunities

The study finds that container technologies offer a variety of benefits and perspectives, but organizations, especially in the public sector, face numerous challenges in implementation.

The use of container technologies enables organizations to develop and deploy their applications effectively and efficiently [19]. Additionally, this technology provides consistent, standardized, and isolated environments for the secure deployment of applications [8]. These technologies are also characterized by flexibility, adaptability, portability, and scalability. This, in turn, increases operational efficiency, improves resilience, and promotes the creativity and innovation capabilities of organizations, especially in the public sector [14, 15, 17]. Consequently, public organizations can respond more quickly to changing requirements and citizen needs. Furthermore, container technologies are lightweight, leading to savings in resource usage and improvements in operational flow and resource management [18]. Container technologies facilitate interaction between different systems and are also used in a variety of scenarios such as microservices architectures, DevOps and CI/CD, cloud-native applications, application modernization, and test environments [19].

On the other hand, regulatory compliance hurdles and requirements regarding the maintenance of security in container orchestration and network facilities pose a significant challenge for public organizations [8]. The consistent implementation of security policies, addressing security concerns related to isolation, and optimizing infrastructure in often very complex environments complicate the use of container technologies in the public sector and can affect operational efficiency [22]. Additionally, the lack of qualified personnel is a hurdle for the optimal use and management of container

technologies in the public sector [22]. These obstacles must be overcome to fully realize the potential of container technology in the public sector.

The review of the literature amply shows how much container technology can transform public sector IT systems. By means of containerizing, public-sector companies will be able to achieve improved operational security, scalability, and efficiency. Addressing the issues they present is necessary to successfully execute security and resource management.

Future Trends

The literature review has shown that organizations, particularly in the public sector, consider the use of container technologies as a significant part of their digital strategy. This technology enables the achievement of scalability and high operational efficiency, as well as meeting the needs of citizens for a wide range of services and high service efficiency. Future developments in the field of container technologies will particularly bring increased flexibility, productivity, security, and cost efficiency to the respective organizations. The increased use of factors such as standardized container orchestration, artificial intelligence (AI), machine learning, the Internet of Things (IoT), cloud-native applications, DevSecOps practices, and continuous integration and delivery pipelines (CI/CD), as well as security improvements, will significantly drive digital transformation in organizations, especially in the public sector [6, 8, 14].

4. Discussion of Findings

Synthesis of Findings

Technological advancements in the use of container technologies result in increased resource efficiency compared to virtual machines (VMs). Additionally, Smith and Johnson (2023) show that the use of AI-based orchestration systems can reduce deployment times by 30% while simultaneously increasing resource utilization by 20% [29]. Lee et al. (2022) have extensively studied container security and found that new security techniques significantly improve the efficiency of IT infrastructures and halve the likelihood of container breaches compared to outdated processes [30]. Studies on the use of container technology in public enterprises at ports have shown a 25% increase in the operational efficiency of logistics performance [31].

Comparison with Previous Research

Recent studies, which mostly focused on the benefits of containerization - including improved resource use and accelerated deployment times - have shown a more advanced knowledge of container security and orchestration than previous studies, which mostly concerned [32, 33].

A 2022 study by Mishra and colleagues definitively showed that containerized software is complex and that a comprehensive Software Bill of Materials (SBOM) is essential for effectively managing vulnerabilities. The study made it clear that without a detailed SBOM, it is difficult to track and mitigate potential security risks in containerized environ-

ments. Continuous monitoring and updating of the SBOM is essential to ensure that all components, including third-party libraries and dependencies, are accounted for and secured against emerging threats [32]. This is not like earlier research that usually disregarded the difficulties of container security. Serverless containers' growing appeal marks a change towards reducing operational overhead and improving development agility [33].

Implications for Practice

The present study on the transformative impact of container technologies, particularly in public organizations, has shown that the associated benefits are diverse and significant. Consequently, organizations can improve their entire production line by achieving greater flexibility, operational efficiency, productivity, resource utilization, and streamlining of IT infrastructure. Additionally, container technology offers high portability, simplifying migration between different cloud environments. It also enables seamless data and information exchange as well as efficient communication between relevant organizations. This promotes collaboration and contrib-

utes to the improvement of service efficiency and the quality-of-service delivery. Security implications in the use of container orchestration should be continuously monitored and addressed. The implementation of security best practices, the use of trusted container images, and the training of experts in handling security threats can significantly minimize potential risks and ensure regulatory compliance [32, 33].

Structure and Use of the Container Platform

The container technology ecosystem (see figure below) represents the entire development and deployment process of container-based applications. This ecosystem, consisting of several subprocesses (development, Continuous Integration/Continuous Deployment (CI/CD), deployment, operation, maintenance), offers high scalability, portability, and resource efficiency for developers and simplifies the development process. Developers can efficiently develop, test, deploy, and manage applications under good security standards. This efficiency particularly benefits public sector organizations, which often need to integrate different systems [20, 22].

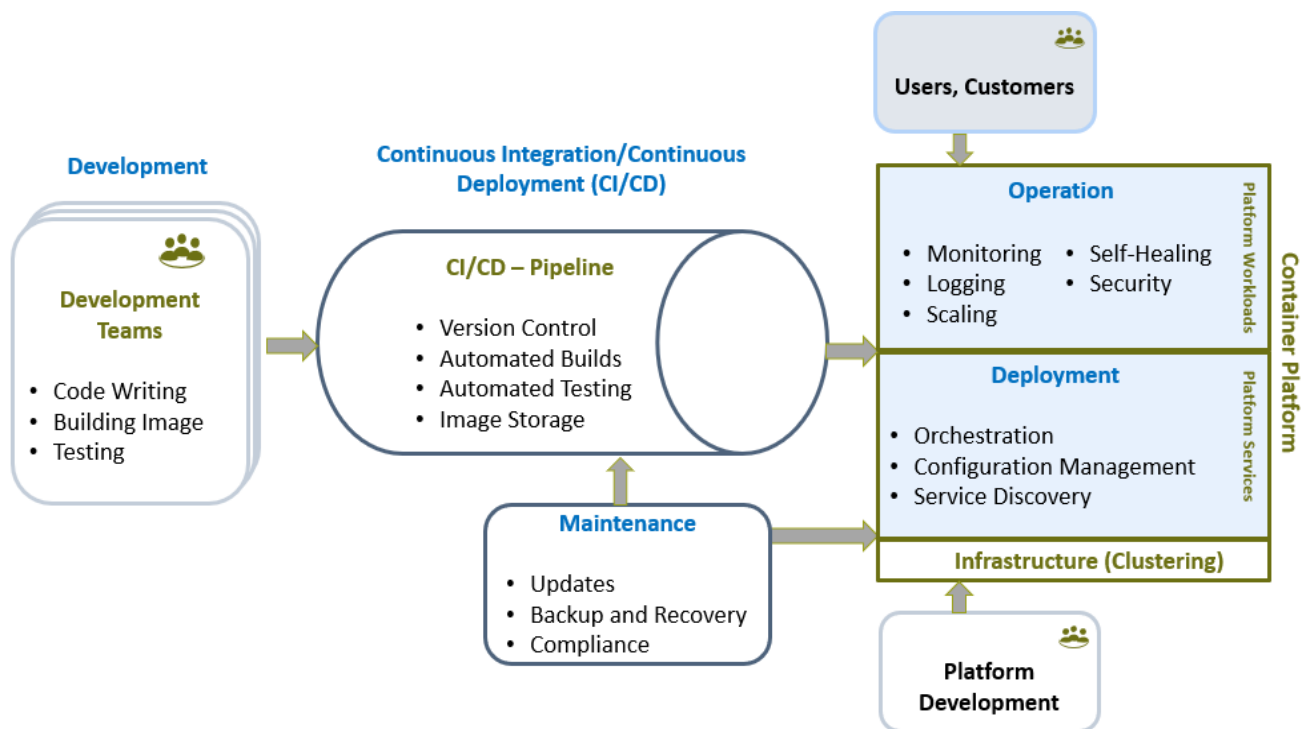


Figure 2. Ecosystem of the container platform (Source: Own representation).

1. **Development:** In the development phase, developers write the application code and use a version control system like Git to manage it. They also create Docker images that contain the application code and all dependencies. Additionally, tests are created, and the build and test process is automated and executed with CI tools like Jenkins [6].
2. **Continuous Integration/Continuous Deployment (CI/CD):** In the CI/CD phase, container images are

stored and managed in a registry like Docker Hub. CI/CD pipelines are also automated to speed up the build process. Additionally, automated tests are conducted with testing tools like JUnit and Selenium [6].

3. **Deployment:** In this phase, Kubernetes is used to deploy and manage the containers. The deployment of applications is automated with the help of CD tools. Additionally, Kubernetes services are used for configuration management to simplify container communication [34].

4. Operation: In this phase, Prometheus is used for monitoring the application, and Grafana is used for visualizing the application. Additionally, logs are stored and analyzed with tools like the ELK Stack (Elasticsearch, Logstash, Kibana). Furthermore, the Kubernetes Horizontal Pod Autoscaler (HPA) is intended for autonomous scaling and includes self-healing techniques to ensure the platform's resilience. Kubernetes Secrets also enable the control of sensitive data to ensure their security [6].
5. Maintenance: This phase is crucial for meeting platform requirements and keeping it up to date. CI/CD pipelines automate the deployment of updates with Velerio and implement backup strategies to mitigate risks. Regular security checks and compliance inspections ensure adherence to laws and standards [34].

The ecosystem enables secure, efficient, and scalable development, deployment, and maintenance of container-based applications.

5. Conclusion and Recommendations

In summary, container technologies offer a range of advantages that increase the flexibility, operational efficiency, and innovation capability of companies, particularly in the public sector, thereby supporting the digitalization strategy of organizations. Additionally, this technology promotes compatibility between different systems as well as collaboration and efficient data exchange between organizations. However, there are challenges in the areas of security, networking, regulation, and a lack of skilled personnel and qualifications that can slow down the adoption of container technologies in organizations.

The findings underscore the critical importance of applying industry standards and effective management procedures to ensure the scalability and security of the container system. In further research, the primary focus should be on developing solutions to the issues that have been identified, as well as researching the ways in which container technology will influence the operations of the public sector information technology department in the long run. Container technology may be fully utilized by public sector organizations to meet the ever-evolving requirements of their digital landscape. This can be accomplished by maintaining a status of innovation and adaptability.

The successful implementation of container technologies in organizations, particularly in the public sector, requires a viable overall strategy for digital transformation that considers the goals, purpose, required expertise, and potential constraints and regulations [28, 6]. Furthermore, the existing IT landscape of organizations and the associated systems should be examined for the integration capability of container technology [6]. Additionally, robust security best practices and standards for containerized environments should be implemented to ensure high data security [28]. Moreover, the use of DevOps and DevSecOps methods can

enhance collaboration and open communication, as well as increase transparency.

Abbreviations

AI	Artificial Intelligence
CIO	Chief Information Officer
CI/CD	Continuous Integration and Continuous Deployment (or Continuous Delivery)
DevOps	Set of Practices That Combines Software Development (Dev) and IT Operations (Ops)
DevSecOps	Set of Practices That Combines Software Development (Dev), Security Practices (Sec) and IT Operations (Ops)
ELK	Elasticsearch, Logstash, Kibana
HPA	Horizontal Pod Autoscaler
IIT	Informatics and Information Technologies
IoT	Internet of Things
IT	Information Technology
OS	Operating Systems
SBOM	Software Bill of Materials
VMs	Virtual Machines

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Author Contributions

Félix Témolé Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resource, Validation, Visualization, Writing – original draft, Writing – review & editing

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Data Availability Statement

Data supporting the findings of this study:
 Location: Datadog: 10 insights on real-world container use
 Link: <https://www.datadoghq.com/container-report/>
 Data related to the search methodology are available in:
 Location: MagentaCloud Share
 Link: <https://magentacloud.de/s/PREtbkpD95KJPcg>
 Password: PAPERCT

Conflicts of Interest

The authors declare no conflicts of interest.

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