Enabling Digital Transformation Using DRA

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Abstract. Digital transformation is about adapting to change using emerging digital technologies such as IoT. The dynamic nature of IoT drives forward the objectives of organizations to enable real-time interconnection between end-users and software products. Real-time interaction is achieved using IoT-applications deployed to multi-cloud. The multi-cloud coherent system provides a broad ecosystem of platform and infrastructure services to support the automated fast delivery of software applications. This article presents the DevOps reference architecture (DRA) for automating the IoT application deployment to multi-cloud in the overall context of digital transformation. The DRA design models are comprehensive blueprints that integrate the contexts of DevOps, multi-cloud, and Internet of Things (IoT). The aim of this paper is to explain how the DRA design models assist in digital transformation by adopting the DevOps approach to support IoT-applications interactions with edge IoT-devices. This paper introduces DRA-DT reference architecture as a holistic approach founded on DRA design models. The DRA-DT provides comprehensive integrated concepts, practices and tools-template that assist Digital Transformation (DT) in organizations. The DRA-DT offers reference models to support the digitization of Agile requirements and can be used by researchers and practitioners as a first-cut platform for support Digital Transformation.

Keywords: Agile · Cloud Computing · DevOps · Digital Transformation · Multi-cloud · Reference Architecture

1 Introduction

DevOps exists to promote efficient enterprise architecture that enables distributed application development [8, 9]. DevOps emerged from the necessity of agile to automate the development process and increase the application delivery frequency [11, 17]. Agile software development is associated with team collaboration and communicated in distributed environment that supports and promotes large-scale development of distributed software application [10, 21]. The adoption of DevOps approach and integration of agile method and DevOps practices empower teams' culture and enhance application performance and improve the product delivery and quality of service [4, 6]. Enterprises may benefit from the agile-DevOps integration to produce architectural model that promotes digital transformation [4, 28]. Agile-DevOps integration aims to architect a roadmap

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to reshape the technological landscape and help non-digitized organizations towards achieving a well-planned and well-managed automated software deployment [2, 19], and [32].

Digital transformation is an emerging phenomenon in the IT industry that aims to improve the organizations' operations by adopting recent digital technologies [14, 32]. Organizations seek to optimize the business process by enhancing product performance and reducing operational costs [20, 35]. IT companies embarked on this trend and applied digital strategies to meet the changing business. However, a vast majority of non-digital companies' profit is gained from non-digital traditional business approach [27, 29]. The question is how to design a platform that enables the digitization of Agile requirements into digital products and provide companies with innovative business models that enhance software development using DevOps?

To address this challenge, this paper presents the DevOps Reference Architecture (DRA) as a Digital Transformation (DT) enabler. The DRA [9, 40] has been evaluated using a research case study [11] and using industry case study [12]. A field survey was conducted to add value and proof that the DRA framework provides novel and comprehensive design models that enable automated IoT-applications deployment to multi-cloud [12]. The paper demonstrates how the DRA design models enable DT and provide the necessary mechanisms and techniques to enhance the performance of IoT-applications interactions with end-users. The DRA shows how Agile requirements can be digitized using DevOps enabled design models.

The main outcome of this paper is a DRA customized models (DRA-DT) that show how industry requirements can be digitized and automated using current technologies. The (DRA-DT) explains how the IoT-ecosystem can drive forward the DT in organizations and how the multi-cloud integrated platforms can offer the necessary technologies and services that can empower the digital transformation in non-digitized IT companies. In the era of enterprise agile, the (DRA-DT) models can enable the automation of the IoT data-driven applications on multi-cloud.

The study begins with a broad literature review that elaborates on the recent related work in the field of Digital Transformation. Secondly, the paper presents an overview of the DRA framework design models. Thirdly, the paper presents the customized DRA into (DRA-DT) transformation models that include an agile strategic roadmap for supporting DT using DevOps core concepts, practices, and tools enabled by the DRA design models.

The (DRA-DT) is expected to provide a strategic and well-managed agile model that enables the automation of technologies and aid IT companies in the process of digital transformation using DevOps.

2 Related Work

This paper discusses the DRA framework that adopts DevOps approach and uses multi-cloud infrastructure to assist the IoT technology. The aim of this paper is to demonstrate how DRA can be used to enable Digital Transformation. Before embarking on this journey, it is essential to discuss the related work conducted in current digital transformations of organizations and businesses.

AL-Zahran [2020] highlights how DevOps practices enhance digital transformation through rapid, reliable software development, using case studies for illustration. Chan

[2021] examines digital transformation's role in sustaining family entrepreneurship in SMEs, with case studies of a traditional manufacturer and a tech-driven small business.

Al-Ali and Phaal [2019] present a road mapping framework for digital transformation, utilizing design sprints to rapidly prototype strategic roadmaps, addressing challenges in achieving successful digital investments.

Bordeleau et al. [2020] focus on creating a DevOps engineering framework for continuous improvement, emphasizing proper modeling with an industry case. Fischer et al. [2020] investigate how BPM aids digital transformation, studying five companies and deriving 17 adaptable recommendations based on six transformation requirements, leading to three strategy archetypes for implementation. Gollhardt et al. [2020] introduce a digital transformation maturity model for IT firms, developed with an energy sector IT company, providing dimensions and criteria for self-assessment and industry benchmarking.

Bosch and Olsson [2021] explore digital transformation in embedded systems companies, noting the shift to service offerings and digital products. Kettunen et al. [2019] study agility in Finnish organizations during digitalization, highlighting priorities like productivity and popular methods such as Scrum and DevOps. Both studies underscore the need for adaptation and agility in response to digital challenges.

Pradhan and Nanniyur [2021] delve into quality transformation in hybrid development, shifting from Waterfall to Agile and CI/CD practices, leveraging ML, AI, and big data technologies. Meanwhile, Moe and Mikalsen [2020] explore agile transformation across business units, stressing a holistic approach for success. Additionally, Schumacher, Bildstein, and Bauernhansl [2020] analyze digital transformation's impact on Lean Production Systems (LPS), identifying key indicators of change. These studies collectively offer valuable insights for navigating large-scale transformations in organizations.

Tongskulroongruang and Chutima [2020] aim to prepare a factory for digital transformation aligned with Thailand 4.0 policy, using SWOT and PEST analyses to develop a strategic plan. Singh and Kongar [2021] propose a value creation model to accelerate digital transformation based on case study insights. Ifenthaler and Egloffstein [2019] develop a maturity model for digital transformation in educational organizations, emphasizing the importance of transparency, methodology, and organizational development for successful technology adoption.

Anthony Jnr. [2020] and Yucel [2018] both delve into digital transformation strategies. Anthony Jnr. Explores using Enterprise Architecture (EA) for sustainable transportation in Electro Mobility (eMobility), stressing data integration's role in cost reduction and citizen services. Employing action research, the study validates EA's contribution to managing data integration for eMobility. On the other hand, Yucel focuses on modeling and evaluating digital transformation strategies for corporations, highlighting the need for a holistic approach considering market dynamics and corporation characteristics. Yucel presents a generic model to aid in this evaluation process.

Tellioglu [2018] presents a model-based approach to guide digital transformation, emphasizing systematic impact assessment and navigation of digitalization's complexities. Rautenbach, Kock, and Jooste [2019] introduce a conceptual model for value-adding digital transformations, identifying six dimensions with validated capabilities for organizations. They structure requirements into phases to enhance digital capabilities. Ribeiro [2020] discusses the evolution of enterprise value chains amidst digital transformation, focusing on data utilization, real-time transformation, and the strategic role of information systems in decision-making and value creation. Overall, these works highlight the importance of strategic models, capabilities, and data-driven strategies in successful digital transformations for organizations.

Wolf, Semm, and Erfurth [2018] highlight the challenges and strategies of digital transformation in Industry 4.0, emphasizing the importance of active knowledge management and agile methods. Hasselbring et al. [2019] propose Industrial DevOps as a solution for Industry 4.0 integration challenges, promoting continuous operation and development in the production environment. Hart and Burke [2020] develop the DevOps strategic IT alignment model, emphasizing continuous software integration and knowledge sharing for successful DevOps implementation and business-IT alignment enhancement.

Alzoubi and Gill [2020] show how Agile enterprise architecture improves communication and performance in distributed Agile teams. They highlight its positive effects on active communication, on-budget completion, software functionality, and quality. Meanwhile, Al-Ali and Phaal [2019] introduce a roadmap tailored for Agile digital transformations, using design sprints to fast-track strategy formulation and suggesting future research directions for enhancing digital transformation planning.

Bou Ghantous and Gill [2017] conduct a Systematic Literature Review (SLR) on DevOps, identifying key concepts, practices, tools, benefits, and challenges. Their study offers insights for practitioners and researchers. Bou Ghantous [2020] explores DevOps in agile software development, particularly for IoT applications in multi-cloud setups. Their doctoral dissertation introduces the DevOps reference architecture (DRA) framework, validated as an effective tool for successful DevOps adoption in multi-cloud environments.

Musikthong and Chutima [2020] focus on machinery and technologies to support digital transformation, aligning with Thailand's Industry 4.0 policy. Maginnis, Hapuwatte, and Keown [2019] integrate True Lean principles with Industry 4.0 for continuous improvement. Mydyti, Ajdari, and Zenuni [2020] explore cloud-based services' role in empowering digital transformation. Pflaum and Golzer [2018] discuss IoT's impact on digital transformation, proposing a strategy-driven approach.

Ahmed and Miskon [2020] focus on IoT-driven resiliency in the Industry 4.0 era, stressing the integration of AI, ML, and analytics for efficient manufacturing systems amid digital transformation. Thoomkuzhy and Thangiah [2021] examine Cloud-IoT integration's impact on organizational performance, highlighting benefits like IoT service management and enhanced application development. They conducted a survey to measure post-implementation metrics. Woodhead, Stephenson, and Morrey [2018] emphasize a shift to a holistic IoT ecosystem in digital construction, urging UK companies to embrace Industry 4.0 and invest in R&D for competitive adaptability.

Guseila, Bratu, and Moraru [2019] stress DevOps' importance in multi-cloud IoT apps for agility and competitiveness, crucial in digital transformation. They introduce a DevOps assessment and plan to use CI/CD pipelines in future research. In parallel, Bou

Ghantous and Gill [2018] propose the DevOps Reference Architecture (DRA) for IoT in multi-cloud environments, aiming to streamline IoT deployment.

Petrova and Lashmanova [2020] focus on personnel subsystems' impact on digital transformation effectiveness. They introduce digital maturity in these subsystems, highlighting its influence on economic indicators. Van Veldhoven and Vanthienen [2021] offer an interaction-driven perspective on digital transformation, aiming for a comprehensive understanding.

Together, these studies underscore the significance of personnel management, interactions, and comprehensive frameworks in enhancing digital transformation effectiveness and understanding across various domains.

3 The DRA Design Overview

The DevOps Reference Architecture (DRA) [40] provides a holistic framework for adopting DevOps in organizations [12]. It integrates DevOps practices with multi-cloud APIs, enabling automated IoT application deployment across multi-cloud platforms using Agile methodologies. This study evaluates the DRA through research and industry case studies, confirming its effectiveness in digital operations and Digital Transformation (DT) facilitation [10, 40].

3.1 DRA Contextual Model

The DRA contextual model (see Fig. 1) is a high-level abstract model that provides an illustration of the relationship between DevOps, multi-cloud and IoT [9].

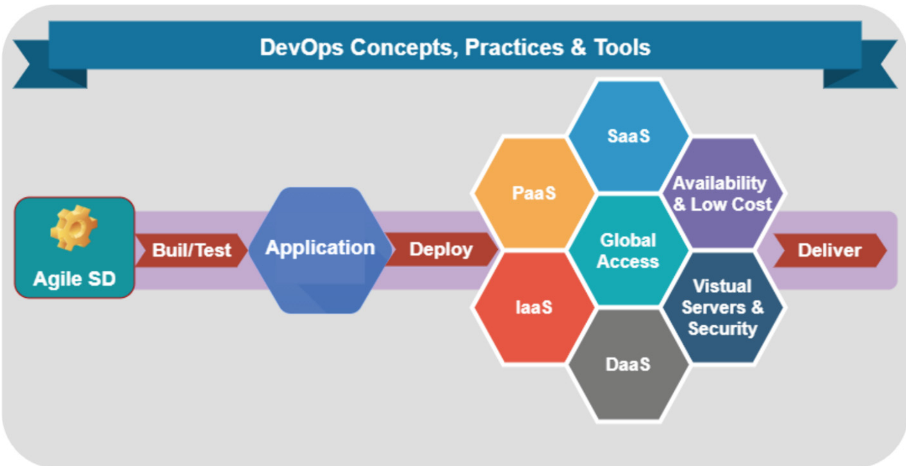

Fig. 1. The DRA contextual model figure illustrates how DevOps approach and multi-Cloud capabilities relationship assist with the Agile Software Development (SD) process.

3.2 DRA Conceptual Model

The DRA conceptual model (see Fig. 2) showcases the integration of DevOps, multi-cloud environments, and IoT, fostering agility. An important enhancement to the DRA is the inclusion of the CI-Broker, a novel DevOps mechanism used to streamline application deployment across diverse cloud platforms [9, 40].

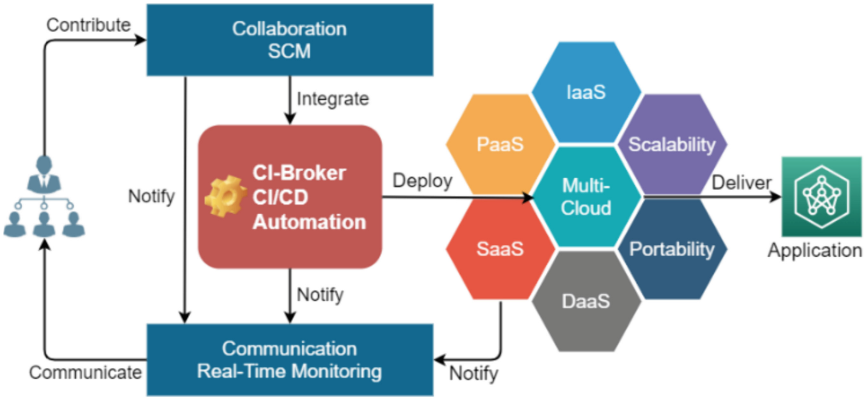

Fig. 2. The DRA conceptual model shows the CI-Broker role in automating Agile CI/CD.

3.3 DRA Logical Model

The DRA logical model (see Fig. 3) translates DevOps concepts into practical functions that blend with multi-cloud services. These functions are based on the best practices in DevOps used by IT professionals and organizations, essentially turning DevOps ideas into actionable practices within the DRA framework [9, 40].

3.4 DRA Physical Model

The DRA physical model (see Fig. 4) provides a tangible template that enables the practices/functions specified in the DRA logical model. The DRA physical model is founded on DevOps tools and cloud services [9, 40]. The DRA physical model can be transformed into operational model by replacing the physical model components by DevOps tools [9, 40].

3.5 DRA Operational Model

The DRA operational model (see Fig. 5) is an instance of the DRA physical model that enables the adoption of DevOps concepts using DevOps tools and cloud services. The DRA operational model (see Fig. 5) is an automated DevOps pipeline that supports Agile SD process and increases the deployment and delivery frequency of soft-ware applications to multi-cloud [9, 10], and [40]. The DRA evaluation [11, 12] explained

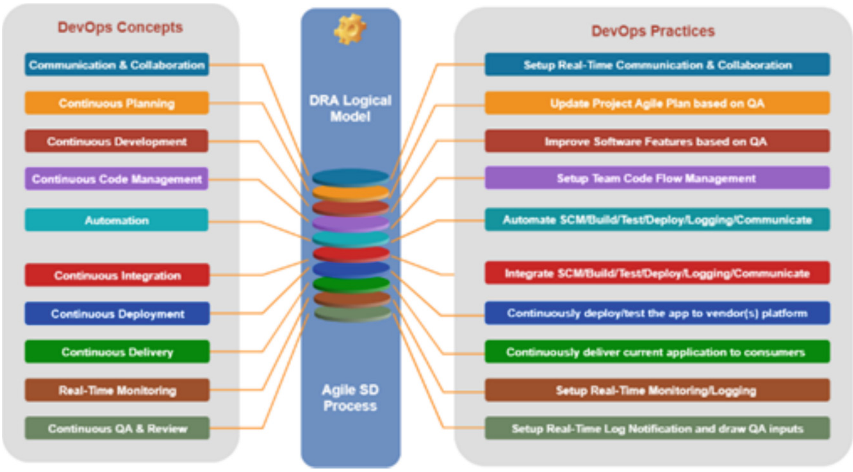

Fig. 3. The DRA logical model transforms DevOps concepts into functional DevOps practices to assist the Agile SD process.

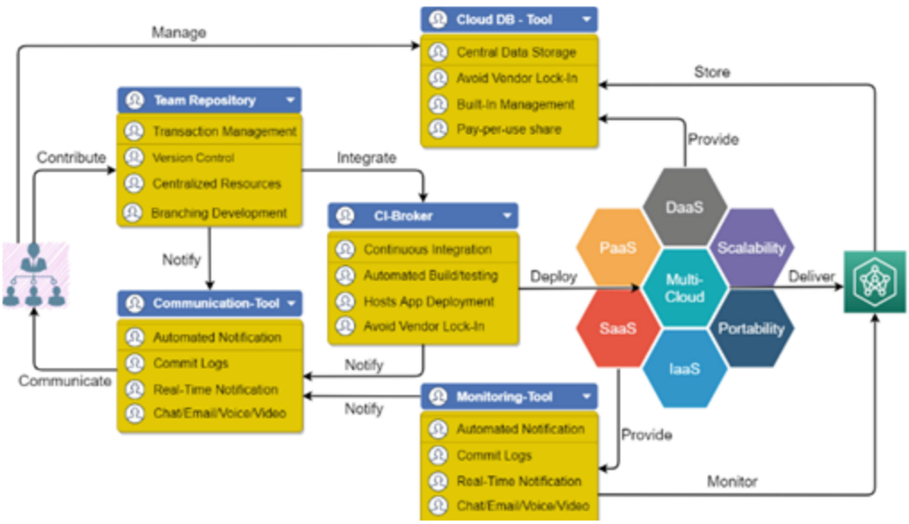

Fig. 4. The DRA physical model template enables the logical model functions and shows the role of the CI-Broker that hosts the deployment parameters for the multi-cloud system.

how the DRA operational model CI-Broker enabled automated and fast application deployment to multi-cloud and how CI-Broker and external central cloud DB helped avoid vendor lock-in.

The DRA operational model provides real-time and effective collaboration and management to the application deployment and delivery [9]. The DRA operational model combines Agile and DevOps best practices to improve product delivery to end-users and obtain fast feedback [11, 12].

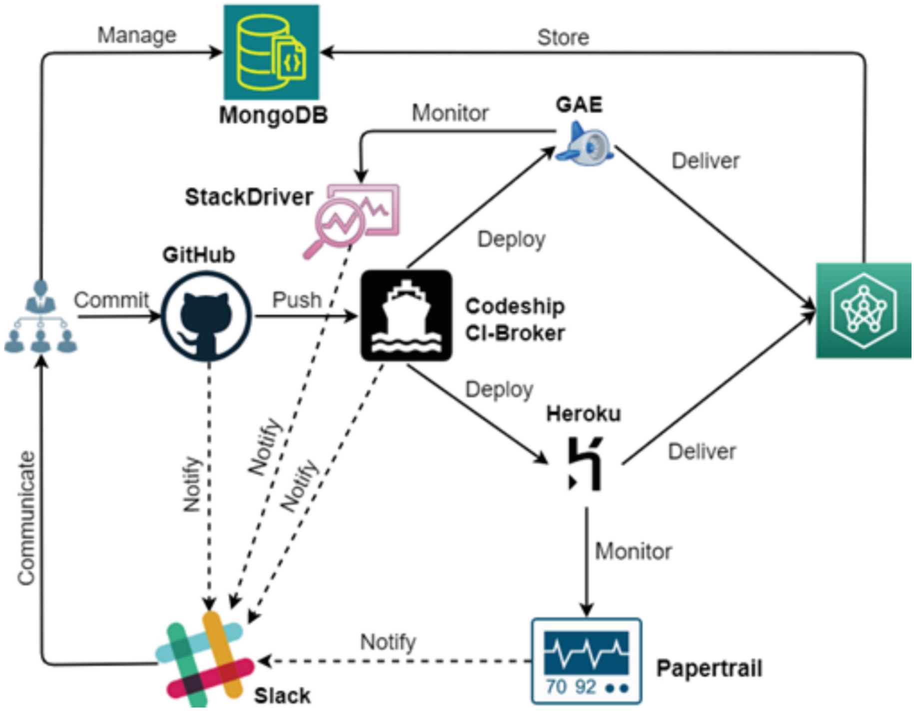

Fig. 5. The DRA operational model CI-Broker (i.e., Codeship, Travis CI) hosts the deployment parameters of the application which prevents vendor lock-in.

4 The DRA-DT Model

The DRA framework facilitates the adoption of DevOps for deploying IoT applications across multi-cloud environments [9, 40]. Built upon core DevOps concepts, the DRA model emphasizes agility, potentially aiding Digital Transformation (DT) [10]. The proposed DRA-DT model modifies existing DRA contextual and conceptual models, acting as a logical transformer that operationalizes agile requirements. The DRA-DT physical and operational models leverage the DRA framework and DevOps tools to create operational pipelines. These modifications are intended to offer a comprehensive understanding of enabling DT through DevOps and agility.

4.1 DRA-DT Contextual Model

The DRA-DT is an abstract framework depicting digitization through agility and DevOps using the DRA model. The DRA-DT context comprises five linear and repeatable steps, with Step 3 translating virtual requirements into functional ones, covering infrastructure and software applications (Fig. 6).

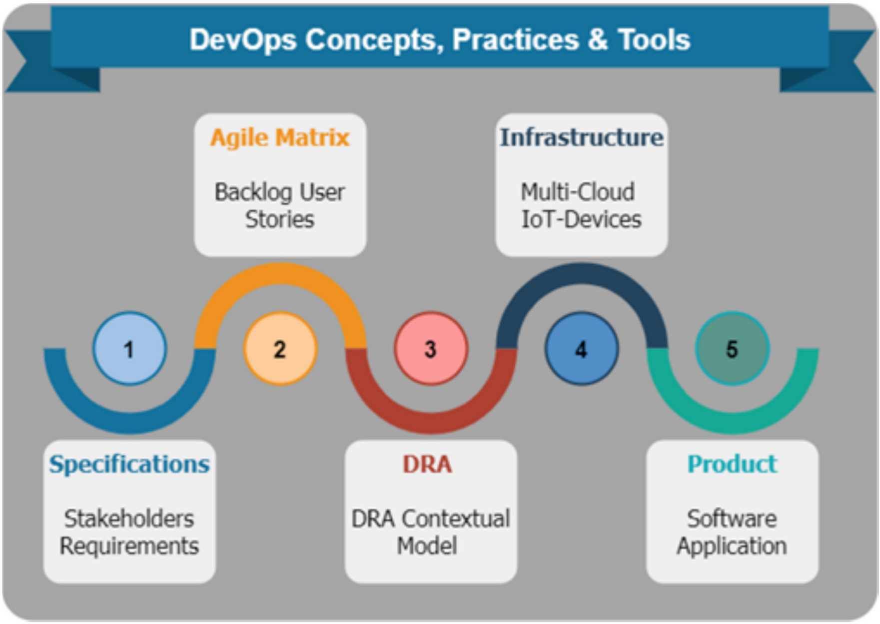

Fig. 6. DRA-DT contextual model illustrates the agile process that transforms backlog user stories into interactive software application using DRA contextual model.

4.2 DRA-DT Conceptual Model

The DRA-DT conceptual model utilizes DRA conceptual model capabilities to empower agility and transform agile requirements into operation units. The agile requirements are derived from stakeholder specifications. The Agile matrix requirements extracted from specifications and mapped into backlog using modern DevOps tools (e.g. Jira).

The DRA Conceptual model includes combined Agile and DevOps practices for fast repeatable development of backlog user-stories into functional requirements. DRA. Agile SD process is vertically accelerated by continuous analysis, planning, design, development, deployment, and delivery. The agile SD steps are enabled by DevOps concepts embedded in the DRA (Fig. 7).

4.3 DRA-DT Transformer

The DRA-DT transformer is founded on the DRA logical, physical, and operational model discussed in Sect. 3. The DRA-DT transformer is composed of three models:

- Team DT model
- Platform DT model
- Product DT model

Team DT Model (Table1) organizes the digitization of the agile team requirements into operations applied by dra logical practices and enabled by DRA operational tools.

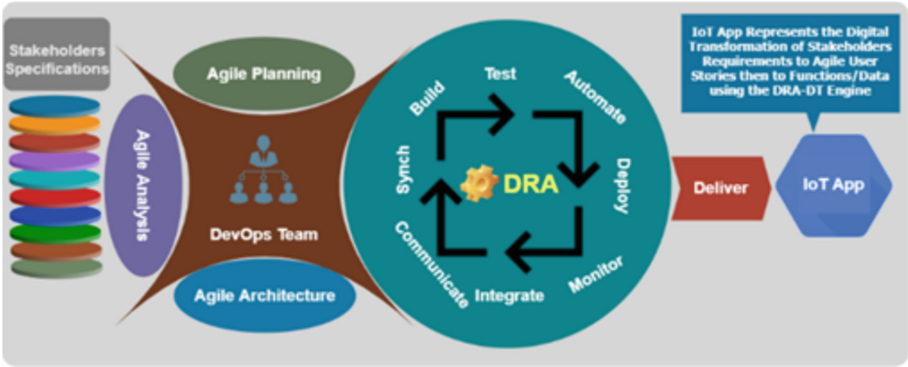

Fig. 7. DRA-DT conceptual model using DRA DevOps concepts to transform stakeholder's specification to agile requirements then to IoT-application.

The DRA offers holistic knowledge about the setup and configuration of DevOps tools that enable DevOps core concepts and practices [9, 40].

Table 1. Team DT Model Transforms Agile requirements to local functions applicable using DRA operational tools.

Agile Team Requirements	DRA Logical Practices	DRA Operational Tools
Team Communication	Setup Real-Time Communication	Slack
Team Collaboration	Setup Real-Time Collaboration	GitHub. JIRA, Confluence
Real-Time Monitoring	Setup Real-Time Monitoring	Papertrail, Stackdriver
Agile Review & QA	Review Application Testing logs	Codeship
Software Analysis	Analyze Testing/Deployment logs	Codeship, Papertrail
Software Planning	Update Project Plan	Agile Backlog, Jira, Confluence
Software Development	Improve Software Features	Open-Source IDE
Software Implementation	Setup Continuous Deployment	Codeship
Software Delivery	Setup Product Auto-Scaling	Heroku, AWS, GAE

Platform DT Model (Table 2). organizes software and hardware components into digital platform. The DRA-DT digital platform is created from IoT-devices and established on multi-cloud heterogenous system enabled by DRA. The platform configuration is outlined on the DRAv2.0 official website [12, 40].

Table 2. Platform DT Model transforms physical components into logical functions to be deployed using DRA Platform tools.

Components	DRA Logical Practices	DRA Platform
Light Sensor	Configure 4 LED Lights	LED, Raspberry Pi
Motion Sensor	Configure Motion Sensor	PIR, Raspberry Pi
Position Sensor	Configure Ultra Sonic Sensor	Ultra, Raspberry Pi
Segment Sensor	Configure Segment Sensor	7Segment, Raspberry Pi
Cloud DB	Setup Cloud DB	MongoDB
Multi-Cloud	Setup Deployment System	AWS, Heroku, GAE
Components	DRA Logical Practices	DRA Platform

Product DT Model (Table3). organizes the digitization of the software application requirements into functional operation units. The digitization process (agile SD process of the IoT application) has been validated using research case study [11], industry case study [12], and industry field survey [12]. The IoT-application automated operations are located on the DRAv2.0 official website [12, 40].

The DRA product operations can be developed using different programming languages. The DRA pipeline used to integrate, test, deploy and deliver the IoT-application sample product can be configured and created using different DevOps tools and different cloud vendors.

Table 3. Product DT Model transforms software requirements into actionable software components.

Software Requirements	DRA Logical Practices	DRA Operations
Activate Light Sensor	Develop operation script	LED.py
Activate Motion Sensor	Develop operation script	PIR.py
Activate Position Sensor	Develop operation script	Ultra.py
Activate Segment Sensor	Develop operation script	7Segment.py
Operate Light Sensor	Develop light-controls GUI	React module
Operate Motion Sensor	Develop motion controls GUI	React module
Operate Position Sensor	Develop ultra-controls GUI	React module
Operate Segment Sensor	Develop segment-controls GUI	React module
Connection Protocol	Setup and Develop connection	MQTT module

4.4 DRA Showcase and Demonstration

The DRA-DT is founded on the principles and architecture of the DRAv2.0 official website [12, 40]. The DRA has been validated in previous research using rigorous qualitative and quantitative methods [11, 40]. This research employs a demonstration video package to showcase the effectiveness and operations of the DRA framework using a practical example based on Table 1, Table 2 and Table 3 models.

Showcase package:

– Demonstration video: https://youtu.be/Ef4RdkN3Wys?si=r-0eQ-ntzwtv5_dE
– Official DRA website: https://draframework.herokuapp.com

5 Discussion

DevOps is the modern phenomenon that empowers agility in organizations and enterprises by accelerating the agile SD process [4] enabled by DevOps core concepts and practices [8, 10, 40]. Agile SD process has become the main trend to designing model roadmap to vertically augment Digital Transformation (DT) [2, 19]. Digital Transformation has become the recent leading form of business transformation for organizations towards model-driven digitization [35]. The process of digitization requires a technology-independent business model [30] that offers strategic plan that supports DT [34, 39]. The development of machineries, such as IoT [22], embedded systems [7], artificial intelligence [1], and e-mobility systems [5], has shaped the DT as a data-driven [25] and interaction-driven [36] operation.

The development of optimal DT approach requires model-based holistic strategic guide [33] that integrates modern trends, technologies, and infrastructures to achieve agility in digitizing the business needs and transform the business requirements into functions [14]. The evolution of DT in the enterprise [29] requires modern technology-independent DevOps models [28] to ignite DT process. The integration of industrial DevOps [17] and cloud-IoT ecosystem [34] provides effective solutions [38] to interactive-DT and demonstrates how DevOps, cloud systems and IoT enable DT in businesses and companies [3, 16].

The DRA outlined in Sect. 3 is composed of five design-models. The DRA design models [9] enable the integration of DevOps, multi-cloud and IoT [40]. IT has been proven that the DRA framework is technology-independent and provides comprehensive knowledge about the adoption of DevOps in organizations [40]. The DRA evaluation using research case study [11], industry case study [12], and industry sur-vey [12] demonstrated that the DRA supports the digitization of IoT-requirements into IoT-applications and enable the automated deployment of IoT-applications (data-driven) to multi-cloud [9, 40]. The DRA design models fit the purpose of digitizing requirements into software and empower agility [10].

This paper proposes a modified DRA (DRA-DT) that provides model-based design to enable digitization. The DRA-DT design models discussed in Sect. 4, empower agile development process, and provide a dynamic roadmap technology-independent to assist with the digitization of organization team, platform, and software requirements. The DRA-DT Transformer includes three models that utilize DRA logical practices to transform team requirements, platform requirements, and software requirements into DRA operations. The DRA-DT models are founded on the DRA logical model functions derived from DevOps core concepts and practices [9, 40].

The DRA-DT can be considered a practical solution for DT in IT. The DRA-DT is a (DevOps, multi-cloud, IoT) conceptual system that empowers digital business transformation and accelerates the agile process of digitization. The core of DRA-DT is founded on automation concepts used in the DRA Framework [9, 40]. The DRA-DT is expected to provide researchers and practitioners with the foundation of DevOps maturity model for DT that influences positively the performance of organizations in the evolution era of enterprise digital transformation.

6 Future Scope and Conclusion

While this paper extensively covers the integration of DevOps for Digital Transformation (DT) using the DRA framework, several avenues for future research and exploration exist. Notably, this study focuses on the operational aspects of DevOps adoption within the context of DT (DRA-DT), but it does not delve into security considerations. Hence, future research endeavors could concentrate on addressing security challenges associated with DevOps implementations in DT initiatives.

- Security Considerations: Given the criticality of data and application security in modern digital ecosystems, future studies could delve into the integration of robust security measures within DevOps practices for DT. This includes exploring strategies for secure code integration, continuous security testing, and implementing security protocols within the CI/CD pipeline.
- Governance and Compliance: Another area for future exploration is the incorporation of governance frameworks and compliance standards into DevOps practices for DT. Research could focus on developing methodologies to ensure regulatory compliance and adherence to industry standards throughout the DevOps lifecycle.
- Ethical and Social Implications: As digital technologies continue to shape societal norms, understanding the ethical and social implications of DevOps-driven DT becomes crucial. Future research could investigate the ethical considerations of automation, AI integration, and data privacy within DevOps frameworks.
- Advanced Automation and AI Integration: Exploring advanced automation techniques and the integration of Artificial Intelligence (AI) into DevOps workflows for DT is another promising avenue. This includes AI-driven decision-making in deployment processes, predictive analytics for performance optimization, and automated anomaly detection for proactive issue resolution.
- Industry-Specific DevOps Frameworks: Tailoring DevOps frameworks specifically for industry verticals could be an area of interest. Research could focus on developing industry-specific best practices, toolchains, and methodologies to optimize DT outcomes in sectors such as healthcare, finance, and manufacturing.

In conclusion, this paper lays a strong foundation for understanding DevOps integration in DT using the DRA framework and provides a practical platform DRA-DT, founded on the DRA models. Future research endeavors should expand into security considerations, governance frameworks, ethical implications, advanced automation, AI integration, and industry-specific frameworks to enrich the discourse and enhance practical implementations in digital transformation initiatives.

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