

Research on the Transformation Path of DevOps in the Digital Era

Xiaoling Niu*, Lingling Yang*, Kailing Liu*, Zhaowei Liu*

*The China Academy of Information and Communications Technology, Beijing, China

niuxiaoling@caict.ac.cn, yanglingling1@caict.ac.cn, liukailing@caict.ac.cn, liuzhaowei@caict.ac.cn

Abstract— DevOps has become one of the most important ways for enterprises to succeed. Enterprises use DevOps to integrate and optimize procedures, such as agile development management, continuous integration, continuous delivery, technical operation, application design, security and risk management (DevSecOps), system and tool construction, monitoring state, and quality assurance. This greatly accelerates the delivery of high-quality software products to users. Combined with agile, lean management, and continuous delivery, this approach has been reconstructing the way to effectively develop cloud service and try out hypothesis safely. Firstly, the flow through the lifecycle, which is divided into plan, design, code, build, test, release, deploy, and operate, should be identified and accelerated by automated test and CI/CD. Then, measurement should be integrated into each part of the flow, and the monitoring system should provide instant feedback. Quality assurance covers the entire lifecycle of development and operation, which is beneficial for identifying defects at an earlier stage and preventing downstream problems.

Keywords— DevOps, agile development management, Continuous delivery, Security and Risk Management

I. INTRODUCTION

With the advent of the digital era, enterprises have gradually discovered the great potential of digitalization. Therefore, smoothing the road of digital transformation has become the focus of enterprise attention.

At present, enterprises have gradually discovered the great potential of digitalization, so how to smooth the road of digital transformation has become the focus of enterprise attention.

The driving factors of enterprise digital transformation are mainly external and internal factors. The external factors are mainly user-driven, technology-driven and competition-driven. User-driven factors mainly reflect users' higher expectations for product capabilities and service efficiency. In recent years, the mature development of new technologies such as cloud computing, big data, blockchain and artificial intelligence has laid a good technical foundation for digital transformation. Competitive drive mainly stems from the competition for products and services within the same industry. The internal factors are mainly a series of internal needs such as strategic planning, business innovation, cost reduction and efficiency improvement, safety and compliance. Strategic planning is reflected in the matching degree and consistency of enterprise strategic transformation; Business innovation is mainly

manifested in the ability of the project team at the organizational level in a unified and service-oriented way to achieve business agility and innovation. Cost reduction and efficiency enhancement mainly show that enterprises need to realize the allocation and application of resource value maximization under the condition of market saturation and increasingly fierce competition. Safety compliance is mainly to standardize the safety and compliance risk system of enterprises and escort the stable and long-term development of enterprises. Driven by both internal and external factors, enterprise transformation has become an inevitable trend.

In the digital era, where “software defines the future”, software has become a key factor in driving industrial upgrading. All things are connected by intelligence, and software enables thousands of activities and industries, which puts forward higher requirements for flexibility, collaboration and precision of software services. The IT department of an enterprise, as the executor of digital transformation, faces increasingly high expectations for digital effectiveness in both the market and enterprise management. This trend, signified by the growing demand for digital solutions, has brought more workload and pressure to IT departments. Consequently, the assessment requirements for IT departments are becoming more aligned with those of business departments.

This paper suggests integrating flexible and changeable business needs with technological innovation. The introduction of DevOps will break the functional silos between traditional Development, testing, and operations department. It will optimize the traditional software development lifecycle management process and shorten the product delivery cycle, adapting to the rapid development of customer needs and market changes.

As shown in Fig.1, the DevOps is commonly regarded as the intersection among the scopes of software Development (Dev), Operation (Ops) and Quality Assurance (QA). DevOps is the culture, process, and technology to foster close collaboration of software development and IT operations^[1-2]. It involves processes, methods, and systems that collectively, through research, development, testing, operation, and maintenance, fill the information gap between various departments. This approach reshapes software development, technology operations, and safety compliance processes in terms of organizational culture. It builds automated toolchains to enhance team collaboration and enables more convenient,

frequent, and reliable software releases through automated, agile, and integrated delivery processes, as shown in Figure 1.

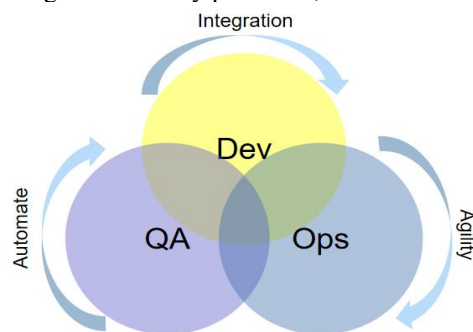


Figure 1. DevOps concept

This paper analyzes the path of enterprise DevOps transformation and industry best practices in the context of digitalization, and provides suggestions on the future trends of enterprise DevOps transformation.

II. KEY ELEMENTS OF DEVOPS TRANSFORMATION IN THE DIGITAL ERA

The key elements of the enterprise's DevOps transformation cover the full lifecycle of end-to-end software development. The specific implementation is divided into six parts: agile development management, continuous delivery, technology operation, application design, security and risk management, system and tool construction, as follows.



FIGURE 2. DEVOPS KEY ELEMENTS

- 1) Agile development management enables enterprises to deliver value through business products and fosters close collaboration among development, testing, and other roles. It adapts to change by employing an evolutionary approach to planning, development, and continuous delivery, allowing for immediate feedback, adjustments, and continuous improvement in a rapidly changing market environment. At present, the main team agile practices adopted by enterprises include Scrum, lean software development, Kanban, extreme programming, and so on^[3].
- 2) Continuous delivery refers to an enterprise's ability to deliver various changes—such as new functions, defect repairs, and configuration changes—safely, quickly, and with high quality to the production environment or users. Companies usually DevOps process can be divided into planning, design, coding, build, test, deployment, distribution and operating stage, using the research, and a

half since the research or commercial tool system or platform, implement DevOps process of development and management, continuous integration, testing, continuous deployment, continuing operations, measure feedback closed-loop management^{[1],[5],[7]}.

- 3) Technical operation is a process that builds enterprise technology capacity. It includes monitoring, incident and change management, capacity and cost management, and management of high availability and business continuity, all centered around the business. This ensures stable, safe, and efficient delivery of technical services, aiming to build industry-leading technical operation capabilities. Support the continuous development and strategic success of the enterprise. Different from traditional technology operation and maintenance, technology operation should not only focus on stability, security and reliability, but also focus on user experience, efficiency and benefit.
- 4) Application design is a crucial horizontal support domain capability for enterprises. By decoupling application and architecture, and considering factors like scalability, testability, and observability, the design architecture can more effectively support the realization of process domain goals, such as agile management, continuous delivery, and technical operation.
- 5) In the DevOps unified development mode, Security and Risk Management (DevSecOps) integrates security into every aspect of work, rather than it being solely the responsibility of the security team. Embedding security throughout the application development lifecycle, while maintaining controllable security risks, enhances enterprise IT efficiency and achieves the integration of research, development, and operation^[4]. We should control the overall risk, the risk of the development process, the risk of the delivery process and the risk of the operation process from four main aspects, by embedding security capabilities into daily norms and tools, with safety training and education means, to reach an internal consensus on security^[6].
- 6) System and tool construction are essential for DevOps implementation. Enterprises need to establish a toolchain that connects the entire end-to-end software delivery lifecycle, encompassing project and development management, application design, continuous delivery, test management, automated testing, and technical operation. The market offers mature open-source or commercial systems and tool platforms, enabling enterprises to choose or develop secondary tools to create a DevOps tool chain tailored to their specific needs^[8].

III. INDUSTRY PRACTICE STATUS

Currently, various industries are adopting DevOps transformation. This includes the communication, Internet, banking, securities, insurance, travel, and tourism industries, among others. Enterprises have comprehensively implemented DevOps practice pilot in the organization, and through the

whole life cycle of software research and development to improve the overall efficiency and quality. The Table 1 shows the result of conventional method in terms of factor for different industry and Table 2 shows the results of DevOps method for different industry. Compared the results in Table 2 to the Table 1, the advantage of DevOps is obvious.

TABLE 1. RESULT OF CONVENTIONAL METHOD IN TERMS OF FACTOR FOR DIFFERENT INDUSTRY

Industry factors	communications	Internet	Banking	securities	Insurance
Requirement lead time	40 days	14 days	50 days	25 days	35 days
Build time	1 hour	10 min	25 min	25 min	1 hour
Continuous integration response time	6 hours	30 min	5 hours	4 hours	1 time/day
Commissioning frequency	1 time/month	1-2 times/weeks	1-2 times/month	2 times/month	1-2 times/month

TABLE 2. RESULT OF DEVOPS METHOD IN TERMS OF FACTOR FOR DIFFERENT INDUSTRY

Industry factors	communications	Internet	Banking	securities	Insurance
Requirement lead time	20 days	7 days	8 days	10 days	7 days
Build time	30 min	3 min	5 min	3 min	20 min
Continuous integration response time	3 hours	20 min	5 min	5 min	Immediate integration
Commissioning frequency	1 time/month	1-2 times/weeks	4-8 times/month	1-2 times/weeks	3-4 times/month

- 1) In the communications industry during the 5G era, the combination of cloud-native technology and DevOps will drive various network functions, including control, management, operation, and maintenance in the telecom network. The commercialization of 5G brings significant changes in services and technologies, such as high transmission rates, low latency, wide connectivity, and virtual software services. These advancements mean not only faster speeds but, more importantly, the ability to adapt to diverse service scenarios and quickly respond to market changes.
- 2) The Internet industry is characterized by rapid business decisions, frequent demand changes, and frequent deployment. Although the software architecture is large and complex, making system maintenance difficult and increasing deployment and operation costs, new technologies are being introduced at a rapid pace. The Internet industry takes the lead in the implementation of DevOps, expanding from team-level pilot DevOps to company-level DevOps implementation practice,

creating a one-stop DevOps research and development platform, which runs through the full life cycle of product development, testing and operation.

- 3) The Banking industry, the financial industry is actively adopting open source software and Internet architecture, gradually transitioning from traditional IT models to fintech. The financial industry has always been in the first echelon of IT technology application development. According to the evaluation data and statistics from the Information and Communication Institute, a number of large banks have successfully implemented DevOps.
- 4) The securities industry, the role of fintech in the securities industry is gradually emerging. Under the background of new technologies and new forms of business, the use of fintech to enable business development, and the combination of fintech with business income, cost reduction and efficiency increase, has become the common concern of securities industry practitioners. At present, the securities industry is also actively building an internal energy efficiency management platform.
- 5) The Insurance industry, Information technology drives the IT scale of the financial and insurance industry to increase significantly, and internal changes are taking place in the IT capability and platform structure of enterprises. Secondly, business scenarios are in urgent need of agile IT operation to cope with the flexible and changeable market demand. The insurance industry can achieve cost reduction and efficiency increase through the construction of efficient platform.

IV. FUTURE DEVELOPMENT DIRECTION

DevOps promotes the transformation and upgrading of enterprise IT operation mode, as well as the improvement and optimization of organizational management process. The construction goal of the enterprise has also been continuously expanded from a single pilot project to the ability improvement at the organizational level. The development trend mainly includes the following aspects.

The enterprise is advocating for transformational governance in application architecture. Conway's law suggests that an organization's structure mirrors its system design, meaning that the design produced by a firm reflects its internal communication structure. With the transformation of enterprise architecture from single architecture to cloud and container architecture, flexible and decoupled application architecture has become the first choice of enterprises. Such application architecture can achieve smooth collaboration among teams and efficient management of IT teams. The transformation and governance of enterprise application architecture is an urgent task.

The enterprise attaches great importance to the development of an integrated security operation system. With the frequent occurrence of all kinds of security incidents, the loss and negative impact to the enterprise is incalculable, and it has become a huge obstacle on the road to the rapid and healthy development of the enterprise. At the same time,

according to National Security Law, and other regulations, clear provisions and requirements are established for information security and control during enterprise digital development. Therefore, enterprises should focus on building DevSecOps capabilities and continuously enhance their security assurance systems. In order to protect the long-term development of enterprise digital transformation.

The multi-scenario application of Intelligent Operation and Maintenance (AIOps) improves enterprise quality and efficiency. According to the analysis of AIOps Status Survey Report, at present, enterprises are facing problems such as expansion of business scale, complex system and explosion of users, which greatly challenge the traditional operation and maintenance mode and increase the difficulty of operation and maintenance. AI, big data and other new-generation innovative technologies can greatly help operation and maintenance personnel improve the quality and efficiency of operation and maintenance work, freeing them to achieve greater breakthroughs and technological innovations.

Measurement of development and operation effectiveness becomes a powerful tool for enterprises to measure the effectiveness of DevOps applications. In recent years, measuring development and operation effectiveness has garnered high-level attention within enterprises. Leading Internet companies like Baidu, Tencent, Alibaba, and JD.com have been exploring engineering practices to enhance development efficiency. This focus on measuring development and operation efficiency aids top management in decision-making and provides insights for transforming research and development processes.

V. CONCLUSIONS

Global enterprises have embraced DevOps as a way to improve business processes. As a new governance paradigm in the field of DevOps, not only refers to a technology or solution, but also emphasizes the communication and cooperation between development, testing, operation and maintenance departments and cultural penetration, so as to improve the efficiency, quality and team culture of software delivery. In the future, more enterprises will practice DevOps, and more enterprises will move forward from DevOps comprehensive level to excellent level. It is also expected that DevOps can achieve integrated innovation and development in the future, and continue to promote the high-quality development of software industry.

ACKNOWLEDGMENT

Corresponding author: Lingling Yang.

REFERENCES

- [1] Prashant Agrawal, Neelam Rawat, "Devops, A New Approach To Cloud Development & Testing", 2019 2nd International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT), pp.982-985.
- [2] Pietrantuono, R., Bertolino, A., De Angelis, G., Miranda, B. and Russo, S., "Towards continuous software reliability testing in DevOps". In Proceedings of the 14th International Workshop on Automation of Software Test, 2019, May, (pp. 21-27). IEEE Press.
- [3] M. Younas, D.N. Jawawi, I. Ghani, T. Fries and R. Kazmi, "Agile development in the cloud computing environment: A systematic review", Information and Software Technology, vol. 103, pp. 142-158, 2018.
- [4] M. Soni, "End to end automation on cloud with build pipeline: the case for DevOps in insurance industry continuous integration continuous testing and continuous delivery", 2015 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM), pp. 85-89, 2015, November.
- [5] Ebert, C.; Gallardo, G.; Hernantes, J.; Serrano, N. "DevOps". IEEE Softw. 2016, 33, pp. 94 – 100.
- [6] A. A. U. Rahman and L. Williams, "Software security in devops: Synthesizing practitioners' perceptions and practices", in 2016 IEEE/ACM International Workshop on Continuous Software Evolution and Delivery (CSED), May 2016, pp. 70 – 76.
- [7] J. Humble and D. Farley, "Continuous Delivery: Reliable Software Releases through Build, Test, and Deployment Automation", 1 edition. Addison-Wesley Professional, 2010.
- [8] Mik Kersten, "A Cambrian Explosion of DevOps Tools ", IEEE Software, March 2018, pp.14-17.



Xiaoling Niu is the leader of DevOps Standards Working Group and the editor of DevOps International Standards. He has been engaged in research work related to development operation and maintenance for a long time, including operation and maintenance management system review and other related work. Participated in the compilation of "Cloud computing Service Agreement Reference Framework", "Object storage", "Cloud database", "Development and operation management (DevOps) capability Maturity Model" series standards, "cloud computing operation and maintenance intelligent general evaluation Method" and other more than 20 standards. Participated in the compilation of several white papers and survey reports, including the White Paper on Enterprise IT Operation and Maintenance Development and the Survey Report on the Status of DevOps in China (2019).



Lingling Yang is currently the Director of the Governance and Audit Department of Yunda Institute of China Academy of Information and Communications Technology, and the Secretary-General of the IT Risk Management Working Committee of the Internet Society of China. She is mainly engaged in the research work of digital governance, focusing on the core fields of XOps system construction, information technology risk governance system, and IT value insight. The initiator of the IT New Governance Leadership Summit (GOLF+), led the establishment of the personal information protection compliance audit pilot program, presided over the completion of more than 10 standards in the field of science and technology governance. Prior to joining the firm, he was a partner in Information Technology and Digital Services at Deloitte Touche Tohmatsu and has more than 13 years of IT governance related consulting and auditing experience.



Kailing Liu, engaged in DevOps, DevSecOps and other IT development research and industry standard formulation work for five years. She is one of the core members of the DevOps industry standard and research work group. She has participated in the preparation of more than six industry standards and five research reports.



Zhaowei Liu is graduated from Nanyang Technological University in Singapore with a master's degree. He has been engaged in related research work in development and operation for a long time. He participated in the preparation of the "R&D Operations Integration (DevOps) Capability Maturity Model" series of standards and the "Business R&D Operations Integration (BizDevOps) Model" and other standards. Participated in the preparation of multiple white papers and survey reports, including the "China DevOps Status Survey Report (2021, 2022, 2023)", etc., participated in the evaluation of more than 40 DevOps capability maturity assessment projects, and has rich experience in standard preparation and evaluation testing.