DEVOPS: A SYSTEMATIC LITERATURE REVIEW

Seminar paper

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Abstract

The DevOps approach is a connection of development and operation teams in software development to supply IT solutions fast into the market. The performed systematic literature review selects 58 out of 842 publications. The number of publications has increased in the recent years as of the importance of DevOps for enterprises rises. For a better understanding the selected literature is categorized in three top (determinants, concepts, outcomes) and each of them in 3 subcategories (context, definition, enablers; collaboration, practices, standards; benefits, challenges, trends). The systematic mapping creates a wide understanding of the term DevOps and suggests a further research on standards in DevOps and the adaptation to large enterprises. Furthermore, future research is needed to discuss DevOps with respects to trends like cloud computing and artificial intelligence.

Keywords: DevOps, Determinants, Concepts, Outcomes.

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1 Introduction

Digital Transformation confronts enterprises with new challenges. The increasing demand of customized IT solutions and the need of supplying software fast into the market becomes crucial to maintain competitive advantages. Especially, incumbents struggle to implement digital strategies to their hierarchical structure and organizational culture. (Sebastian *et al.*, 2017, pp. 198–199) Along with these, development IT teams in enterprises get more and more important and so-called shadow IT teams are built up to cover the increasing demand of IT competence within enterprises. (Dornenburg, 2018, p. 71) Due to the need of digital transformation, IT teams must adapt new technologies and enroll a customer centric approach. The earlier software development approaches like Waterfall Model, Spiral Model were replaced by agile practices like Kanban and Scrum. Nowadays, DevOps is the state-of-the-art software development approach with focus on agile concepts and operational aspects. (Perera *et al.*, 2017, p. 1)

The metaphoric term DevOps provides the keynote of the DevOps approach: The connection of development and operation teams in the discipline of software development. (Fitzgerald and Stol, 2017, p. 176) Digital giants like Amazon and Netflix already use DevOps to deliver perfectly fitting customer-centric software solution to the market. (Zhu *et al.*, 2016, p. 32)
That's why DevOps is an often-discussed term when it comes to software development and fast delivery of customer demanded software solutions. But what is DevOps exactly, what determinants, concepts and outcomes are relevant? A systematic mapping of publications is necessary to answer that question. The following systematic literature review of DevOps analyses all relevant literature on a quantitative and qualitative level, which results in a detailed overview of the mentioned dimensions and an outlook on future research.

Structure of the paper

The paper starts with a brief introduction to DevOps, before the literature review in section two is conducted. Within section two are three sub-sections, which cover the review method, the process and its outcomes. The selected literature is structured in a table with nine sub and three main categories. Afterwards, a quantitative and qualitative analysis of the selected literature is done. The results are used as the fundament for the discussion in section four. The closing part of this paper is a conclusion of the findings together with an outlook on a future research. The focus of this paper is a wide mapping of current publications in regard to DevOps.

2 Literature Review

This paper deals with a systematic literature review which focus on the general term *DevOps.* The literature review includes all relevant literature which doesn't rely only on one research methodology, one set of journals, or one geographic region. (Webster and Watson, 2002, p. 5) To understand the whole process and technique in detail, the following section explains how the literature was filtered and selected. The search was applied to three databases and two of them have a specific focus on information technology. The third one is a recognized economical database.

2.1 Review method & Search string

The search string in all databases is *DevOps.* The choice of a very general search term helps to get a very wide overview. Within the databases the search was not filtered, and no date range was conducted. The search is processed in IEEE Xplore, ACM Digital Library and EBSCO Information Services. All three databases are recognized research databases in the field of information technology or economics. The search results in a total count of 842 publications, which includes also duplicates. After identifying

duplicates, the number of publications is still 715. To get a handy number out of that huge amount of literature, a certain process must be applied.

First, deleting all results in non-English languages. Afterwards the identification of relevant literature follows by checking the title. This step is very important to get rid of the irrelevant publications, which aren't focusing on DevOps. Then, the abstract of remaining literature is read and analyzed with respect to the general search term DevOps. It's very important to select literature that focus on different aspects of DevOps but without being that specific or technical. Next, all publications are downloaded as full text. The last step is the skim of the selected literature for categorizing similar focused literature in categories. At best, it's also possible to create top and subcategories for describing the selected literature very precisely.

2.2 Selection criteria and process

As explained in the previous section, the process starts with the general search of the term DevOps in all databases and results in 58 relevant publications, which is shown in table 1.

Table 1: Result of search in IEEE, ACM and EBSCO conducted in April 2019

Step	Count of result in IEEE, ACM and EBSCO
Search with term DevOps	842
Deleting duplicates	715
Deleting of non-English literature	705
Relevance by title	218
Relevance by abstract	95
Relevance by full text	58

The table 1 shows a total number of 58 publications which are relevant for this literature review on the term DevOps. The following section covers the categorization of all 58 publications into three top categories and for each 3 subcategories.

2.3 Selected Literature

All selected 58 publication are grouped into three top categories: Determinants, concepts and outcomes. Like mentioned before, each of the three top categories are split in three subcategories to have a more detailed view. The category determinants is split in enablers, definitions and context; concepts in collaboration, practices and standards; outcomes in benefits, challenges and trends.

The table 2 Literature Matrix shows the distribution of content over all selected publications.

Table 2: Literature Matrix

DevOps											
			Determinants			Concepts			Outcomes		
Title	Author	Year	Enabler	Context	Definitions	Collaboration	Practices	Standards	Benefits	Challenges	Trends
001._Toward unified DevOps model	A. Wahaballa	2015		X	X			X			
002._Composable DevOps Automated Ontology Based DevOps Maturity Analysis	M. A. McCarthy	2015	X	X	X		X	X			
007._Understanding DevOps & bridging the gap from continuous integration to continuous delivery	M. Virmani	2015			X		X	X	X		
012._The Path to DevOps	E. Därnenburg	2018	X	X		X					
017._DevOps Introducing Infrastructure-as-Code	M. Artac	2017	X			X	X	X			
022._Improve software quality through practicing DevOps	P. Perera	2017	X	X					X		
023._Towards a full-stack devops environment (platform-as-a-service) for cloud-hosted applications	Z. Li	2017									X
026._Versioning Strategy for DevOps Implementations	N. Paez	2018	X				X				
040._DevOps culture and its impact on cloud delivery and software development	M. Rajkumar	2016	X		X	X					
054._DevOps	C. Ebert	2018				X	X				
055._Modern DevOps Optimizing software development through effective system interactions	C. A. Cois	2014				X		X			
057._Continuous practices and devops beyond the buzz, what does it all mean	Daniel Stahl | Torvald Martensson | Jan Bosch	2017	X	X	X		X	X			X
063._Continuous scrum A framework to enhance scrum with DevOps	S. S. Samarawickrama	2017		X				X		X	
069._SecDevOps Is It a Marketing Buzzword - Mapping Research on Security in DevOps	V. Mohan	2016	X	X	X		X				
076._ResearchOps The case for DevOps in scientific applications	M. de Bayser	2015			X		X	X		X	
120._Five Predictions for the Coming Decades of Software	M. Kersten	2018									X
138._Don't Install Software by Hand	D. Spinellis	2012	X	X			X				
255._Monitoring in a DevOps world	Theo Schlossnagle	2017		X							
256._Object-Oriented Programming with DevOps	Sam Chung	2017						X			
257._DevOps Metrics	Nicole Forsgren and Mik Kersten	2017		X			X				
264._DevOps Capabilities, Practices, and Challenges Insights from a Case Study	Mali Senapathi and Jim Buchan and Hady Osman	2018	X	X	X				X	X	
267._Software security in DevOps synthesizing practitioners' perceptions and practices	Akond Ashfaque Ur Rahman and Laurie Williams	2016		X		X	X		X		
277._An Agile Framework for ITS Management In Organizations A Case Study Based on DevOps	Sahid Abdelkebir and Yassine Maleh and Mustapha Belaissaoui	2017						X			
284._The Impacts of Digital Transformation, Agile, and DevOps on Future IT curricula	Charles Betz and Amos O. Olagunju and Patrick Paulson	2016		X	X						
286._DevOps Performance Engineering A Quasi-Ethnographical Study	G.Vergori and D. A. Tamburri and D. Perez-Palacin and R. Mirandola	2017					X				
297._DevOps for Better Software Security in the Cloud Invited Paper	Martin Gilje Jaatun and Daniela S. Cruzes and Jesus Luna	2017	X	X	X			X			
299._SQL Is No Excuse to Avoid DevOps	Thomas A. Limoncelli	2018			X		X			X	
304._From DevOps to BizOps Economic Sustainability for Scalable Cloud Applications	Marios Fokaefs and Cornel Barna and Marin Litoiu	2017	X		X				X		
313._Towards Definitions for Release Engineering and DevOps	Andrej Dyck and Ralf Penners and Horst Lichter	2015		X	X						
318._Introduction to the Special Issue on Emerging Software Technologies for Internet-Based Systems	Akond Ashfaque Ur Rahman and Laurie Williams	2016	X		X						
336._A DevOps Collaboration Culture Acceptance Model	T. Masombuka and E. Mnkandla	2018				X					
338._Delivering Elastic Containerized Cloud Applications to Enable DevOps	Cornel Barna and Hamzeh Khazaei and Marios Fokaefs and Marin Litoiu	2017	X				X		X		
418._Is DevOps another Project Management Methodology	BANICA, Logica	2017	X	X	X		X	X	X		
436._IS DEVOPS THE BEST APPROACH TO SOFTWARE DEVELOPMENT	Bamforth, Rob	2018			X		X		X	X	
442._CHALLENGES AND BENEFITS OF DEVOPS IN THE PUBLIC SECTOR.	Shah, Sooraj	2018		X					X		X
446._BARRIERS TO ENTERPRISE ADOPTION OF DEVOPS	Donnelly, Caroline	2017							X		
447._Can DevOps deliver on digital potential	Saran, Cliff	2017	X						X	X	
452._How CIOs can implement a DevOps Culture	Mercer, Christina	2018	X		X						
460._HOW TO SCALE UP DEVOPS IN THE ENTERPRISE	Donnelly, Caroline	2016					X			X	
465._12 tips for using DevOps to fuel digital transformation	Boulton, Clint	2017	X		X				X		
468._DevOps Goes Mainstream	Gale, Sarah Fister	2018							X		
491._Keep the Focus on the Business to Succeed with DevOps.	Gowda, Bharath	2016						X	X		
696._Continuous and Integrated Software Development using DevOps	Aayush Agarwal, Subhash Gupta, Tanupriya Choudhury	2018	X		X		X			X	
698._Can DevOps deliver on digital potential	Saran, Cliff	2017								X	
699._A Large Agile Organization on Its Journey Towards DevOps	Kati Kuusinen, Veena Balakumar, Sune Chung Jepsen, Simon Hjortshøj Larsen,	2018							X	X	X
700._Characterizing DevOps Culture A Systematic Literature Review	Mary Sánchez-Gordón, Ricardo Colomo-Palacios	2018	X	X	X						
703._Continuous Software Engineering and BeyondTrends and Challenges	Brian Fitzgerald, Klaas-Jan Stol	2014	X	X	X						
706._Tooling up for DevOps	Longbottom, Clive	2017					X				
707._DevOps and Its Practices	Zhu, Liming; Bass, Len; Champlin-Scharff, George	2016		X			X				
708._Performance Issues Hey DevOps, Mind the Uncertainty	Trubiani, C.; Jamshidi, P.; Cito, J.; Shang, Weiyi; Jiang, Zhen Ming; Borg, M.	2019					X			X	
709._Report DevOps	Floris Erich, Chintan Amrit, Maya Daneva	2014	X			X		X			
710._What is DevOps A Systematic Mapping Study on Definitions and Practices	Binish Tanveer; Ramtin Jabbari, Nauman bin Ali,	2016	X	X	X		X				
712._Revamping the IT Curriculum with Agile and DevOps Methodology	Amos O Olagunju	2018			X						
714._Model-driven continuous deployment for quality DevOps	Artač, M.; Borovšak, T.; Di Nitto, E.; Guerriero, Michele; Tamburri, Damian A.	2016	X								
715._DevOps	Christof Ebert, Gorka Gallardo, Josune Hernantes, and Nicolas Serrano	2016	X	X			X				
716._Integrating DevOps within IT Organizations- Key Pattern of a Case Study	Anna Wiedemann; Manuel Wiesche; Heiko Gewald and Helmut Krcmar	2018	X	X	X	X					
719._DevOps_ Concepts Practices Tools Benefits and Challenges	Georges Bou Ghantous;Asif Gill	2017			X		X		X	X	
721._Introducing-DevOps-to-the-Traditional-Enterprise-final	Manuel Pais	2014								X	X

3 Results

Based on the selected literature a detailed analysis is conducted. It starts with a superficial descriptive analysis which focuses on the publish date. Afterwards, a very detailed qualitative analysis of the literature of each category is proceeded.

The result list includes also a DevOps Literature Review (Floris Erich *et al.*) which was published in 2014. It focuses mainly on culture of collaboration, automation, measurement, information sharing and web service usage. As a conclusion it stated that DevOps have a positive effect on operational performance, IS development, quality assurance performance. But a further research on these statements is needed to verify the hypothesis in that early state of the DevOps evolution. (Floris Erich *et al.*, p. 1)

Other found systematic literature reviews deal with the culture of DevOps (Sánchez-Gordón and Colomo-Palacios, 2018, p. 3) and the definition of DevOps (Jabbari *et al.*, 2016, p. 1).

3.1 Quantitative Analysis

As mentioned in the section introduction, DevOps is a very modern term, so that the first publications with focus on DevOps are dated in year 2011. After 2011 there is a continuous growth of published papers because of the increasing relevance of DevOps in the industry. The graph below shows an approximately linear course of the graph, which underlines the increasing relevance of the term DevOps. Gartner shows in the hype cycle in 2017 that DevOps is straight on its way to peak of inflated expectation and could result in a reduction of publications. (Gartner, 2017, p. 1).

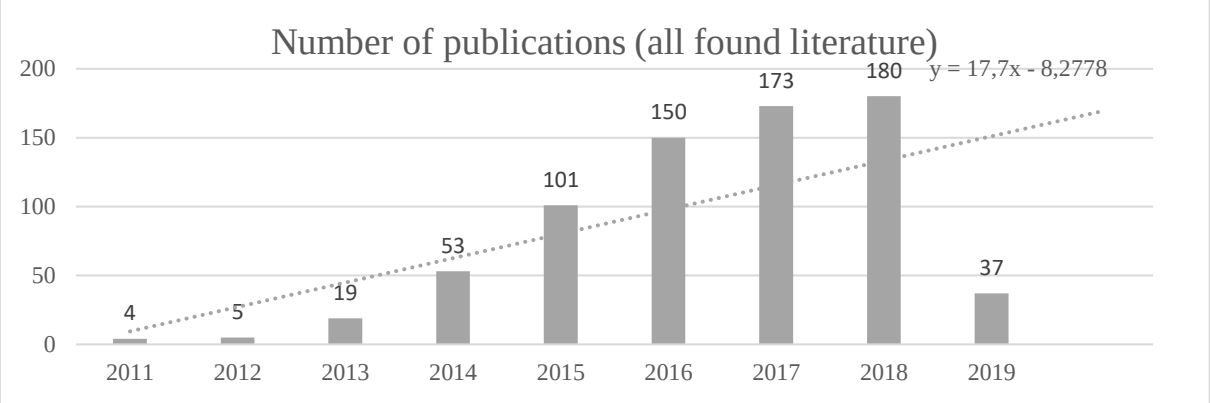

Figure 1: Number of publications of all found publications

The distribution of selected literature of 58 publications shows clear the focus on newer publication to see if there is a development how DevOps is seen in the literature.

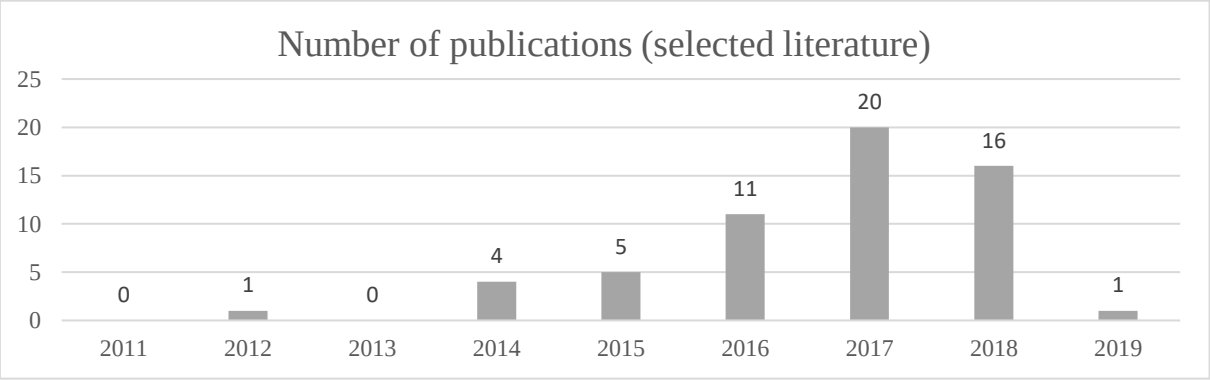

Figure 2: Number of publications of selected publications

The conducted descriptive analysis shows that DevOps isn't a clearly stable term and the development in several dimensions is still ongoing. Based on these results it's necessary to investigate on the content layer how DevOps is seen in respect to the shown categories and how the focus in literature might have been shifted over the years.

3.2 Qualitative Analysis

In comparison to the descriptive analysis the qualitative analysis focus on the content of each category.

3.2.1 Determinants

The following section determinates is stripped down into the category's context, definitions and enabler of DevOps. The paragraph starts with context, continues with definitions of DevOps and closes the section with enablers of DevOps.

Context
Over the past years the importance of IT in a business context exceeded a lot and enterprises must focus on IT solutions. (Dornenburg, 2018, p. 71) This development requires often a digital transformation of the business which leads to new challenges in the IT departments. Associated therewith, many enterprises face a high pressure from the market to adapt new capabilities for digital strategies and software development. (Mikusz *et al.*, 2018, p. 157) The recent software development world stand for long release cycle, static development methods and fix time periods. (Schlossnagle, 2018, pp. 58–60) Examples for previous methodologies are Waterfall, PMBOK, PRINCE2 and Agile. (BANICA *et al.*, 2017, pp. 39–40).

Nowadays, the development of software has totally different requirements. Sustainable competitive advantages are gained through a fast delivery of customer wanted features. At best, the feature is carried out in real time which satisfies the customer demand immediately. At this point the term continuous kicks in. (International Workshop on Rapid Continuous Software Engineering *et al.*, 2017, p. 1) Continuous delivery describes the way of defining every change of code as a new potential release for production. The code is forwarded to the continuous delivery pipeline in which it waits to get the approval to go productive. (Stahl *et al.*, 2017, pp. 440–441) The same applies to the transition between software development to its operational deployment which should be continuous, too. (Fitzgerald and Stol, 2014, p. 1) By describing the involvement of the development teams into operational processes, DevOps is paraphrased. (Farroha and Farroha, 2014, p. 288) In addition to the following paragraph, this is a very rudimental definition of the term DevOps so that a systematic mapping of definition shows how DevOps can be defined.

Definitions
The selected literature offers many different definitions and characteristics for the term DevOps. (Fitzgerald and Stol, 2017, p. 176) Although nearly all sources agree on the fact that DevOps is a combination of Development and Operation, it isn't enough to explain what DevOps exactly is. (McCarthy *et al.*, 2015, p. 605) Many publications define DevOps as a method of principles which enables communication between Development and Operations Team. (Olszewska and Waldén, 2015, p. 12) Some focus on bridging the gap between the two teams, (Wettinger *et al.*, 2016, p. 318) others say that it is a development method or software delivery technique (Guerriero *et al.*, 2015, p. 29) and a few define DevOps as automated deployment, continuous integration or quality assurance. (Hosono and Shimomura, 2012, p. 397) Tanveer et al present a very detailed definition of DevOps: "DevOps is a development methodology [...] aimed at bridging the gap [...] between Development (Dev) and Operations [...] , emphasizing communication and collaboration [...] , continuous integration [...] , quality assurance [...] and delivery [...] with automated deployment [...] utilizing a set of development practices." (Jabbari *et al.*, 2016, p. 8)

"[Other publications keep a more holistic definition which defines DevOps as an] umbrella concept that encompasses people, processes, and technologies required to connect development to execution."

(Gunnar Menze, 2015, p. 5) This indicates that DevOps have different viewpoints which seem to polarize but all approaches end up in the connection of Development and Operation. (Bamforth, p. 18) That implicates a transmission to various disciplines in information technology. For instance, Security in DevOps is named as SecDevOps and DevSecOps. Both include the collaboration of security teams with development and operations teams to portray the whole process from development to productive operation. (Mohan and Othmane, 2016, p. 542) Another example is the Project Management view on DevOps that involve the project management Team in the DevOps methodology. (BANICA *et al.*, 2017, p. 40)

Summarizing, there isn't a unique definition of DevOps because the term can be applied to many areas of the software development and operation. But the overall message, the combination of development and operation in different fields of software development is clear.

Enablers

Enablers in terms of DevOps can be very different and wide-ranging. DevOps practitioners John Willis and Damon Edward introduce the CAMS model to structure the enablers of DevOps. CAMS stand for culture, automation, measurement and sharing, which are named as the four-fundamental dimensions to enable DevOps. (Humble and Farley, 2011, p. 42)

Along with this, culture is identified as important building block, which creates an environment of collaboration. (BANICA *et al.*, 2017, p. 43) Often, culture change is seen as the start of the DevOps because with this change development teams begin to interact with operational teams. These social interactions or in general human activities a crucial for the development of the software (Hussain *et al.*, 2017, pp. 22–26) and get supported by a collaborative culture with flatten hierarchies. (Mercer, 2018, p. 1) In addition to the very human based view in terms of culture, automation focuses more on technical aspects. Automation means the use of specific tools to automate the process from development to operation. Build automation, test automation, deployment automation, monitoring automation, recovery automation, infrastructure automation, configuration management for code and infrastructure must be supported by adequate tools. (Lassenius *et al.*, 2015, pp. 168–172) Companies like Amazon and Google tend deploy multiple times a day by supplying small updates to the productive environment. (Ebert *et al.*, 2016, p. 94) The next aspect of the CAMS model is the need of measurement in a DevOps environment. All actions and processes must be mirrored in KPI's to measure the delivery capability and the implementation of a continuous improvement framework. (Humble and Molesky, 2011, pp. 6–8) To get this process automated, the mentioned tools must cover the documentation and if not, additional tools must be implemented into the DevOps framework. The last aspect of the CAMS model is sharing. The category sharing deals with tools, culture, ideas, problems, sessions learned and data. The gained openness and transparency allow an effective cooperation between development and operation teams. Like mentioned in the model, DevOps is about culture, automation/tools, measurement and sharing, but none of these terms can enable DevOps by its own. (Humble and Farley, 2011, pp. 2–4)

3.2.2 Concepts

The section concepts consist of the subcategory's collaboration, practices, and standard. Especially, the subcategory practices are a wide-discussed topic regarding DevOps. What practices are the most common and are there any standards in the DevOps market? The following paragraph provides an overview of collaboration, practices, and standards in the literature.

Collaboration

DevOps is all about the connection of Development and Operation and this requires collaboration. A culture of collaboration releases the opportunity that people with different knowledge, skills and abilities collaborate. (D. DeGrandis., 2011, pp. 34–39) Cross-functional teams create more value across the delivery chain of software than isolated silo-based teams. (Dornenburg, 2018, p. 75) But to create a successful collaboration environment four element are identified as crucial: open communication,

alignment of responsibilities and incentives, respect and trust. An open communication across team members and between teams helps to avoid conflicts and duplication of work. (Walls, 2013, pp. 5–6) Furthermore, the mutual understanding of developers and operators perspectives is improved in an open communication environment. (Cheng *et al.*, 2017, p. 643) Another important aspect is the clear alignment of responsibilities and incentives within and across teams. In particular, if a quick reaction to a situation is necessary, teams with aligned responsibilities are able to act in short period of time. (Bosselut *et al.*, 2012, p. 345) But open communication and the alignment of responsibilities and incentives don't support collaboration if trust and respect are not present in the collaborative structures. (Walls, 2013, pp. 6–7) Besides the human based collaboration, DevOps are also about automated communication throughout the SDLC in a technical system. The system must be designed to transfer and extract data of its components. But an isolated automated system is not the key to success in collaboration, human must have the possibility to adjust, interact and process the data. (Cois *et al.*, 2014, p. 4) Summarizing an internal platform is used to gather all information, data and processes of technical systems and human teams. (Mikusz *et al.*, 2018, p. 164) These mergers relieve development and operation teams from their silos and support the collaboration a lot. (Artac *et al.*, 2017, p. 497)

Practices

DevOps is about automation, continuous delivery, collaborative culture and bridging the gap between development and operation teams. To get all the mentioned concepts in place, tools are mandatory. Especially, the aspect of automation heavily relies on the right tools for the environment. (Ebert *et al.*, 2016, p. 95) There isn't any single DevOps tool (Gunnar Menze, 2015, p. 18) that covers all aspect like container management, continuous integration, orchestration, monitoring, deployment, and testing. That's why huge organizations tend to development their own customized tools. (Zhu *et al.*, 2016, pp. 33–34) The goal of nearly every tool is the reduction of manual time-consuming tasks and/or build automation. Built tools can also handle the software development and service life cycle. (Ebert *et al.*, 2016, pp. 96–97)

Beyond that there are no limitations regarding the number and type of tools in a DevOps environment. For instance, Security tools can be added into the development architecture to cover security, monitoring and logging aspects. (Farroha and Farroha, 2014, pp. 290–291) But with the increasing number of tools the risk is given that more than one tool covers a certain task and a side-by-side usage of tools across the different team arises. That's why it's very important, that all developers, operators and system administrators are on the same set of tools. Otherwise the merged systems can collapse, and the different teams work against each other. Because of the complexity of setting up the right tools in a certain environment, more and more companies provide a broad set of capabilities in form of a platform. IBM, AWS, Google, Microsoft are just a few examples for vendors of platforms with tools for continuous development. (Limoncelli, 2018, p. 49) "[Examples for tools are] Jenkins and Codeship (continuous integration, continuous testing), Puppet and Ansible (cloud management), New Relic and AWS CloudWatch (monitoring), Bitbucket and Github (repository), MongoDB (NoSQL database management), and HipChat (DevOps team communication)." (Ghantous, Georges Bou and Gill, Asif, 2017, p. 4) The listing of these tools' underlines, that there are many existing practices in DevOps without any standardized use, which is presented in the following paragraph.

Standards

First, DevOps doesn't implicate any specific process or framework. It isn't a specific solution approach to fix a single engineering problem like Scrum. And there isn't a certain process or standard available which defines a step-by-step proceeding. DevOps must be seen in a more holistic way, so that there isn't a need of defining one standard for DevOps but is makes sense to combine the DevOps approach with standards like CMMI and ITIL. (D. DeGrandis., 2011, pp. 28–35)

With the adaption of DevOps in Organizations, the organization need to redefine structures and dependencies to allow for instance a cross-functional collaboration. (Humble and Molesky, 2011, pp. 10–11)

This does not mean that the organization must get rid of existing methods and systems because an integration of DevOps principles to the existing methods is always possible. For instance, Disciplined Agile Delivery is an enterprise process model which includes a DevOps layer in this model. The Disciplined Agile toolkit consists of four layers of which the second is called Disciplined DevOps. (Scott Ambler, 2011, pp. 19–24) The same applies to the approach of combined Scrum methods, which also includes components of DevOps. The so-called Continuous scrum model is a framework to optimize scrum with DevOps. (Samarawickrama and Perera, p. 7)

Another approach of defining a DevOps model is the so-called UDOM Model, which allows organizations to adapt and maintain DevOps in a successful way. That model is structured in three sub models: Application and data model, Workflow execution model and Infrastructure model. By providing the mentioned structure, questions like what, how and where in terms of adapting and maintaining DevOps should be answered. (Wahaballa *et al.*, 2015, pp. 211–212) In addition to that, the so-called generalized model for DevOps is based on the Software Development Life Cycle, Agile Software Methodologies and Data-Driven Development and Communication and maps interrelations between several systems. Central elements of this model are issue tracking, build, documentation systems, code review system, monitoring systems, communication system and source control. This model provides a formulized approach to guide the organization of responsibilities, DevOps infrastructure, and automated systems for software development teams. (Cois *et al.*, 2014, pp. 2–6) Another example for a transfer of DevOps principles to a certain standard is the integration of DevOps in ITS Management. The principles of DevOps help to improve the management of ITIL and IT services. (Abdelkebir *et al.*, 2017, pp. 6–7)

3.2.3 Outcomes

Benefits

In 2017 a survey of 705 IT professionals stated that 83% will start adapting DevOps by 2019. Facts like that lead to the conclusion that DevOps provide huge benefits for organizations. (Saran, 2017, p. 1) One of the central aspects of DevOps is the term continuous in various dimensions. The benefits heavily depend on the way DevOps is optimizing and automating processes. (Bamforth, p. 19) By adapting DevOps successfully, it reduces development time, enhances deployment rates, increases stability of the project, optimizes Mean Time to Recover (MTTR) and reduces cost of deployment and implementation. (Puppet Labs, 2015, pp. 8–11)

The main reason for gaining advantages in comparison to the traditional waterfall approach is the fact, that DevOps is data driven and merges separated teams. (Gowda, 2016, p. 30) This results in a greater productivity, better applications and improved customer satisfaction. (Saran, 2017, p. 15) Especially large organizations who are often known for separate silos, have a high potential to improve their development and operation of software products in all departments. Primarily, the continuous customer feedback should have a direct impact on the product to increase the customer satisfaction. And this is at the end of the day, the key to business success. (Chen, 2015, pp. 52–53)

Challenges

Challenges in DevOps are multifarious, because human and technical aspects are touched, and operation and development teams have often different views. For instance, the operation team relies on stability and reliability, whereby the development team looks for change and new innovative tools. This can be very challenging for the communication bridge for both teams. (Agarwal *et al.*, 2018, p. 292) Focusing further on human aspects, the DevOps adaption needs the right people in the right position. People tend to fall in habits, but with the right leadership style it is possible to change. (Donnelly, 2016, p. 17) That's the reason why getting the right DevOps talents is so significant. (Saran, 2017, p. 18)

Apart from human skills and behavior, DevOps in a rather technical perspective is mainly about automation, which is based on tools and systems. A fraction of DevOps targets is reaching of a continuous level of deployment, delivery and integration. This includes an automated rollback because the

deployment is done many times a day. Often, the rollback methods aren't effective and result in operational issues. (Kamuto and Langerman, 2017, pp. 48–49) Furthermore, many organizations still proceed manual quality checks of the code although an automated deployment method is in place. (Agarwal *et al.*, 2018, p. 292) These examples illustrate that DevOps scenarios can have sources of uncertainty which have to be identified and addressed. Creating a control model and performing sensitivity analyses help to overcome uncertainties. (Trubiani *et al.*, 2019, p. 110) But all these challenges are even harder to overcome in larger organizations. Often silo structures have last for many years and employees used to practice non-agile methods. (Bayser *et al.*, 2015 - 2015, p. 1400)

Trends

Like mentioned before, in the past years the IT industry has changed and topics like cloud computing, virtual environments and artificial intelligence have become big deals in the IT world. Digital giants like Amazon, Microsoft, and Google provide in a tremendous speed new opportunity in their cloud technologies. While Software-as-a-Service products are well known by many end users, Platform-as-a-Service (like Google App Engine and Docker) is mainly unknown for end-users but plays an important role for cloud developers. PaaS system are perfect to quickly build and deploy cloud applications so that DevOps is much easier to adapt in an environment like this. (Li *et al.*, 2017, pp. 1–2) This doesn't mean that DevOps is only practical in a cloud environment, but DevOps can help to generate business value more efficiently. (Jez Humble et al., 2014, p. 10)

Another upcoming trend is Artificial Intelligence. Machine intelligence grows and will have a huge impact to all business fields in the near future. Likewise, the traditional programming approach will shift to data modelling and fully automated processes which requires human communication to control the input and outputs. And this is where DevOps will gain even more importance than it already has. (Kersten, 2018, p. 9)

4 Discussion

What we know

The conducted systematic literature review provides a broad overview of the term DevOps. The increasing number of publications underlines the importance of DevOps in a digital world. IT solutions decide about business success and enterprises look for solutions to satisfy the increasing demand of customized IT solutions. Regarding the need of suppling customized solutions fast into the market, enterprises, especially traditional, large organizations, struggle to fulfil customer requirements of digital products. Traditional software development approaches like Scrum, and Prince II fail because of the non-agile proceeding.

In addition, a continuous delivery of digital products develops a fulfillment of customers' needs and arises satisfaction. To get there, enterprises adapt DevOps to merge operational and development teams. Based on this fact many publications agree that DevOps combine the operational and development side of software development. The target is an unobstructed connection of both teams, which enables a communication and make the delivery of software faster and more convenient to the customer needs. Other definitions are more detailed but based on the findings, it's more accurate to keep a holistic definition to include all aspects of DevOps. Summarizing, there isn't a homogeneous definition in the literature but nearly all definitions have the connection aspect of both teams in common.

In contrast, enablers of DevOps are structured in the CAMS model which is a recognized model in the DevOps literature. The four dimensions culture, automation, measurement and sharing cover all relevant factors of DevOps. The first-dimension culture is often associated and linked with collaboration. Furthermore, the view on culture is human based as automation deals with tools and systems, which is more on the technical level. An open communication is the basis of all other dimensions and is crucial for the adaption process of DevOps. It's even harder to connect teams with a higher number of team members in large organizations who used to work in separate silos than to link teams in smaller enterprises. In small organization teams are often physically in one place and due to a less standardized delivery process exists a more intensive communication.

That's the reason why tools play an important role in DevOps and many practitioners associate DevOps with the use of specific tools. It's important to mention that there isn't one DevOps tool. The selection of the right tools in the right environment with the right people is the key to adapt DevOps. Hence, big digital giant who delivery software multiple times a day, tend to develop their own DevOps platforms, which combine tools in an effective way. But there isn't a certain standard like CMMI or ITIL, which include a detailed framework to implement. Nevertheless, many organizations plan to adapt DevOps in their organization because they want to benefit from higher productivity, lower delivery time, automated processes and greater customer satisfaction. But the continuous adaption process of DevOps in organizations contains many challenges on a technical and human level. Reasons can be different views on facts of development and operation teams, human nature, technical barriers, leadership, distrust and uncertainty. The technical barriers of practicing DevOps become more and more irrelevant, because cloud systems open the opportunity to delivery software to an unlimited number of clients within seconds. Whereas the challenges on a human level increase due to the fast development of IT products in the digital world. Combined with the increasing demand of state-of-the-art IT-solutions in the market and unpredictability of upcoming innovations, enterprises need to focus on leadership aspects to adapt DevOps successfully.

What we don't know

DevOps constitute a general approach for software development without a unique standard or framework. That's probably one of the reasons why many enterprises struggle to adapt DevOps. On the one hand the enterprise can define how their DevOps culture, collaboration, and tools look like but on the other hand the free determination of elements in the organizational DevOps framework is often challenging. Furthermore, the literature doesn't provide a model which helps to adapt DevOps to an existing infrastructure. A few models deal with the combinations of known standards like ITSM, CMMI and ITIL with DevOps, which is a feasible approach to make DevOps more concrete for practitioners. This leads to the fact that DevOps and other software development approaches have similarities which can help to adapt DevOps in an enterprise.

Apart from the challenge to adapt DevOps in an enterprise, the operation in a DevOps environment is also challenging. The literature doesn't provide recommendations or a model how to deal with the different views of development and operation teams. That's the point where leadership can play an important role.

Due to upcoming innovations and the development of existing technologies the demand of DevOps will increase and might require new approaches. Technologies like artificial intelligence and machine learning will change the existing style of coding and software development. How does DevOps take this into account? Especially, large enterprises must turn into agile organizations to satisfy the upcoming customer demand of new and innovative technologies.

Limitation

The conducted systematic literature research includes three scientific libraries so that relevant literature in other databases is missed out. Furthermore, all non-English literature is excluded from the research and the found literature refers to the single search string DevOps. Another limitation is the selection bias itself, although the steps are documented. Finally, the categorization is done by a single researcher.

5 Conclusion

The literature review shows the increasing importance of DevOps for many companies in the digital transformation process. One the one hand the increasing number of publications proof this, on the other hand the literature does no longer focus on what DevOps and the enablers are. Instead, the literature concentrates on tools, practices and the lack of standards.

Along with this, the literature doesn't provide an adequate framework or process to adapt DevOps to an existing IT environment in enterprises. Especially large companies struggle to adapt DevOps to their existing software development departments in order to provide their customers innovative software products. Some publications deal with similarities of different software development standards and try to include DevOps in certain frameworks. But this isn't enough to overcome the mentioned difficulties as a large enterprise. That's why a further research is necessary. Furthermore, new techniques like cloud computing and artificial intelligence in combination with DevOps are not described in a detailed way. But the relevance of DevOps in combination with cloud-based web applications grows and digital giants like Amazon and Netflix have already a working DevOps environment in place. Here is also a further research needed.

In summary, the literature review provides an overview of the term DevOps and identifies gaps for further research. And it's important to state that DevOps isn't a stable term. It fulfills the requirements of modern software development and increases the customer satisfaction.

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