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Maturity Model for DevOps

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Resumo

Hoje em dia, as empresas precisam de responder às necessidades dos clientes a uma velocidade sem precedentes. Impulsionadas por esta necessidade de velocidade, muitas empresas apressam-se para o movimento DevOps. O DevOps, a combinação de Desenvolvimento e Operações, é uma nova maneira de pensar no domínio da engenharia de software que recentemente recebeu muita atenção. Desde que o DevOps foi introduzido como um novo termo e um novo conceito, ainda não foi alcançado um entendimento comum do que significa. Portanto, as definições do DevOps geralmente são apenas uma parte relevante para o conceito. Ao observar o DevOps, o fenómeno aborda questões culturais e técnicas para obter uma produção mais rápida de software, tem um âmbito amplo e pode ser visto como um movimento, mas ainda é jovem e ainda não está formalmente definido. Além disso, não foram identificados modelos de adoção ou modelos de maturidade refinados que mostrem o que considerar para adotar o DevOps e como fazê-lo crescer. Como consequência, esta pesquisa tentou preencher essas lacunas e, consequentemente, apresentou uma Revisão sistemática da literatura para identificar os fatores determinantes que contribuem para a implementação de DevOps, incluindo os principais recursos e áreas com os quais ele evolui. Isto resultou numa lista de práticas por área e por capacidade, que foi utilizado como base nas entrevistas realizadas com peritos em DevOps que, com a sua experiência, ajudaram a atribuir níveis de maturidade a cada prática. Esta combinação de fatores foi usada para construir um modelo de maturidade de DevOps mostrando as áreas e as capacidades a serem levados em consideração na sua adoção e maturação.

Palavras-Chave: DevOps, Maturity Model, CMMI, Capacidades, Areas.

Abstract

Businesses today need to respond to customer needs at unprecedented speed. Driven by this need for speed, many companies are rushing to the DevOps movement. DevOps, the combination of Development and Operations, is a new way of thinking in the software engineering domain that recently received much attention. Since DevOps has recently been introduced as a new term and novel concept, no common understanding of what it means has yet been achieved. Therefore, the definitions of DevOps often are only a part relevant to the concept. When further observing DevOps, it could be seen as a movement, but is still young and not yet formally defined. Also, no adoption models or fine-grained maturity models showing what to consider to adopt DevOps and how to mature it were identified. As a consequence, this research attempted to fill these gaps and consequently brought forward a Systematic Literature Review to identify the determining factors contributing to the implementation of DevOps, including the main capabilities and areas with which it evolves. This resulted in a list of practices per area and capability that was used in the interviews with DevOps practitioners that, with their experience, contributed to define the maturity of those DevOps practices. This combination of factors was used to construct a DevOps maturity model showing the areas and capabilities to be taken into account in the adoption and maturation of DevOps.

Keywords: DevOps, Maturity Model, CMMI.

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Abbreviations

CD	–	Continuous Deployment
CI	–	Continuous Integration
CMMI	–	Capability Maturity Model Integration
DSR	–	Design Science Research
DSRM	–	Design Science Research Methodology
ITIL	–	Information Technology Infrastructure Library
MM	–	Maturity Model
SD	–	Software Development

Chapter 1 – Introduction

The constantly change of business needs and the requirement for faster time to market with today's software has created a paradigm shift towards a 3rd generation Software Development (SD) philosophy adopting DevOps principles and practices. The lack of collaboration between IT Operations and SD as well as mismatch in configuration between development, testing and production environment has made deploying software releases slow and painful for many organizations. Different incentives between teams makes it difficult to work towards a common goal of bringing added value to customers.

A SD methodology in software engineering is a framework that is used to structure, plan, and control the process of developing an information system. Traditional and modern (agile) SD methodologies usually focuses exclusively on the SD teams. In either case, once the software is developed, it is typically handed over to the IT operations team, which takes responsibility for its deployment, ongoing maintenance and support (Jones, Noppen, & Lettice, 2016). The Agile movement has brought together programmers, testers, and business representatives. Conversely, operations teams are isolated groups that ensure stability and enhance performance by applying practices such as the Information Technology Infrastructure Library (ITIL) (Hüttermann, 2012).

For Debois (2011), since both development and operations serve the same customer, the needs of both must be discussed simultaneously. Treated separately, they are like separate trains on separate tracks: no matter how fast they go, they can never meet. Due to this fact, the team commonly works in silos, which leads to a lack of information exchange. Lwakatare, Kuvaja, and Oivo (2015a) say that it is impossible to effectively transmit information between two different teams in continuous release mode, while de França, Jeronimo, and Travassos (2016) report that Development and Operations are left to themselves and will often struggle to talk to each other, much less collaborate, and will remain mired in manual processes. As a result, employees do not work well together, software not work reliably, and customers think about moving to competitors (de França et al., 2016).

Separations on a technical and organizational level as well as the use of different tools have experienced an increase among Dev and Ops teams (M. M. A. Silva, Faustino, Pereira, & Silva, 2018). This bottleneck between Dev and Ops can affect and/or compromise products and services' quality. So, there is a clear disconnect as the two teams speak two different languages (McCarthy, Herger, Khan, & Belgodere, 2015).

In the midst of such evidence, DevOps emerged. It applies agile and lean principles throughout the entire software supply chain (Sharma & Coyne, 2015). These principles of lean development are: eliminate waste, build quality in, create knowledge, defer commitment, deliver fast, respect people and optimize the whole (Razzak, 2016). This allows a business to maximize the speed of delivery of a product or service, from the initial idea to production release and all the way up to customer feedback to improvements based on that feedback (Sharma & Coyne, 2015).

Mohamed (2015) argues that this level of integration between development and operations is revolutionary as releases can be driven by the business need, rather than the operational constraints. Virmani (2015) adds that this approach helps to deliver value faster and continuously, reducing problems caused by misunderstandings between team members, and help to accelerate problem resolution. In another perspective, DevOps can be understood as rendering operations more agile (Hüttermann, 2012).

According to de França et al., 2016 there is a lack of common understanding of what DevOps means for both academia and the practitioners' communities. This knowledge gap demonstrates that there is still a need for research about the DevOps phenomenon, its complexity and lack of support and orientation on the sequence of steps to adopt/implement/achieve DevOps. Based on what has been described, there is a clear opportunity to develop a Maturity Model (MM) on the subject, with the goal of deepening our understanding of what DevOps is.

1.1. Motivation and Objectives

In recent years, the advancements on DevOps area have facilitated a lot of new growth opportunity for software companies (Nidagundi & Novickis, 2017) as it improves the way how a business delivers value to its customers, suppliers, and partners, it is an essential business process, not just an IT capability (Sharma & Coyne, 2015). This is one of the main reasons why the DevOps' adoption is growing and is a new tendency in business and IT alignment (Bucena & Kirikova, 2017). To Chen (2018), businesses today need to respond to customer needs at unprecedented speed. Driven by this need for speed, many companies are rushing to the DevOps movement and implementing Continuous Delivery.

The growth opportunities for DevOps continue to increase. Ovum, a market-leading data, research and consulting company**,** sees plenty of evolution potential in DevOps as there is potential for improved integration with Application Lifecycle Management on the dev side and improved integration with operations and IT business

services (Azoff, 2016). According with the 2018 State of DevOps Report has been registered a steady increase in survey responses from people on DevOps teams, from just 16 percent in 2014 to 29 percent in 2019 (Velasquez, Kim, Kersten, & Humble, 2018).

The adoption of DevOps drives a challenging cultural shift towards collaboration and knowledge-sharing between SD, quality control and operations (Colomo-Palacios, Fernandes, Soto-Acosta, & Larrucea, 2018). The tremendous growth in demand for DevOps has, however, led to the appearance of new needs. For St, Ab, and Bosch (2017), despite wanting to implement DevOps, many companies find it difficult to understand what DevOps is and what advantages it will have. Furthermore, they ask themselves how to implement DevOps or how can they improve their DevOps practices.

Many companies miss the maturity of the concept – with no clear definition of DevOps and its practices, no clear goals available and a lack of understanding about development workflow phases and responsibilities (Bucena & Kirikova, 2017). There is both a lack of understanding around DevOps and a clear definition of what it is (Lwakatare et al., 2015). Therefore, organizations are not sure how to effectively implement DevOps capabilities (Qumer Gill, Loumish, Riyat, & Han, 2018).

The disruptive nature of the changes required to adopt DevOps leads to organizational and business stress. While L. Zhu, Bass, and Champlin-Scharff (2016) consider the organizational strains as being standard for new technologies, for Bucena and Kirikova (2017) the adoption of DevOps is not trivial and can require complex changes in an enterprise's process, organization and workflow. To succeed in adopting DevOps, the enterprises should understand the different aspects that are related to the DevOps approach and have a well-thought-out strategy. They should start the adoption process with a clear idea of what actions should be performed, how they should be prioritized, what tools could support these actions, and how to measure the success of the adoption process (Bucena & Kirikova, 2017). Moreover, the way an organization is structured may influence DevOps' adoption, for example, when discussing communication, common goals and practices, decision making, and systems thinking within the organization (Smeds, Nybom, & Porres, 2015).

Whereas DevOps benefits are widely discussed regarding DevOps culture and available tools, it makes sense to exist a MM for DevOps approaches. A MM is a widely used technique that has proven valuable for assessing business processes or certain aspects of organizations, as it represents a path towards an increasingly organized and systematic way of doing business. (Proenca, 2016). They also allow for a better

positioning of the organization and help find better solutions for change (Becker, Knackstedt, & Pöppelbuß, 2009).

As organizations are under constant pressures to gain and maintain competitive advantages, identifying ways of cutting costs, improving quality, reducing time to market and so on, they become increasingly important.

1.2.Research Objectives

In this section, the researcher will explain how the research objectives will be addressed. According to the literature, both areas and capabilities play an important role in DevOps adoption and maturation. Therefore, the researcher has defined that studying the key areas and capabilities that relate to DevOps should be an integral part of this research.

Based on the previously presented information in the last section, the researcher defined the following objectives:

RO1: To develop a MM for DevOps

RO1.1: Identify DevOps capabilities

RO1.2: Identify DevOps Areas

1.3.Structure

The remainder of this dissertation consists of eight chapters that are structured as follows. The second chapter presents the Theoretical Background, about DevOps and MM. The third chapter presents the related work, studies related with DevOps MM. In the fourth chapter, the author presents the Research Methodology that was used on this study. In the fifth chapter, it is presented the design phase. In the sixth chapter, it is present the development and demonstration of our implementation and the respective results. In the seventh chapter, the Evaluation and Communication is assessed. In the eighth chapter, our conclusions, possible future work and the felt limitations along dissertation are presented.

Chapter 2 – Theoretical Background

The clarification of concepts and definitions, related to our topic and derived from existing theories and empirical studies available in the academic literature, is provided in this section. The topics that will be further detailed are DevOps and MM.

2.1. DevOps

A good cooperation between IT Development and IT Operation teams is viewed to be crucial in order to ensure successful deployment and operations of IT systems (Tessem & Iden, 2008). However, for historical reasons, most IT organizations are characterized by clear boundaries between these two teams, which have very different goals, mindsets and cultures (Swanson & Beath, 1990; Gazivoda, 2018).

According to Sharma (2014), many organizations are not successful with software projects and their failures are related to the challenges in product development and delivery. Despite this, many companies find that the development and delivery of software applications are crucial to their business, and that only 25% of companies consider their teams to be efficient (Sharma, 2014). This gap in efficiency leads to many losses of business opportunities. This demonstrates that even a disruptive methodology cannot be perfect for every project.

Given the distinct nature and typology of the functions of each of these teams, it is easy to understand why there are some conflicts when they interact. Such conflicts are essentially related to the different focuses of both teams. Despite actively seeking collaboration from all its stakeholders, most agile projects do not extend themselves to operations people (Diel, Marczak, & Cruzes, 2016). These two teams (Operations and Development) should maintain a close and agile relationship, as it is this relationship which represents the stream of values between the business (where requirements are defined) and the customer (where value is created) (Kim, 2015).

However, the relationship between Dev and Ops is not always linear and transparent enough to be able to create synergies capable of overcoming new problems that appear throughout the application's life cycle. While Dev is focused on faster innovation and doing new things, Ops is mainly focused on stability, control, and predictability (Tingley & Anderson, 1986). This cultural difference between the development and operations departments has been reported to lead to conflicts. For example, developers need to get used to operation personnel not having experience with working on projects (J Humble & Molesky, 2011). When development and operations are divided into different

departments, some processes cross departmental boundaries. This makes it difficult to automate these processes (DeGrandis, 2011). For Debois (2011), despite the fact that both development and operations serve the same customer, the needs of both should be discussed at the same time.

According to Virmani (2015), as part of the Agile transformation in the past few years, IT organizations have introduced Continuous Integration (CI) principles into their software delivery lifecycle, which has improved the efficiency of development teams. Over time, however, it became clear that the optimization resulting from CI was not helping to make the entire delivery lifecycle efficient nor to increase the efficiency of the organization. Unless all the pieces of a software delivery lifecycle work like a well-oiled machine, the efficiency of the delivery lifecycle cannot be optimized.

In order to address the problems between the development and operations teams a new agile approach appeared, namely DevOps. DevOps has been heralded as a novel paradigm to overcome the traditional boundaries between IT Development (Dev) and IT Operations (Ops) teams (Nielsen, Winkler, & Nørbjerg, 2017). According to Riungu-Kalliosaari et al. (2016), DevOps is a set of practices intended to reduce the time between making a change to a system and this change being placed into normal production, while ensuring high quality. The main goal associated with this concept is to avoid common problems when operations and developers are kept as separated teams (Bezemer, Eismann, Ferme, & Grohmann, 2018).

In a more general approach, DevOps integrates a set of characteristics and principles for software delivery that focuses on: speed of delivery, Continuous Testing in a an environment where production takes place, being ready for shipping at any moment, continuous feedback, the ability to react to change more quickly, and teams working to accomplish a goal instead of a task (no more team boundaries causing a delay) (Sharma & Coyne, 2015). It involves an organizational paradigm shift from distributed siloed groups performing functions separately to cross-functional teams working on continuous operational feature deliveries. Instead of confining themselves to highly artificial process concepts that will never fly, organizations set up continuous delivery with small upgrades (Ebert, Gallardo, Hernantes, & Serrano, 2016).

DevOps integrates the two worlds of development and operations, using automated development, deployment, and infrastructure monitoring (Ebert et al., 2016). For Sharma and Coyne (2015), because DevOps improves the way that a business delivers value to

its customers, suppliers, and partners, it is an essential business process, not just an IT capability.

2.2. Maturity Model

Software organizations deploy software process improvement (SPI) initiatives as a way to enhance software product quality (Staples & Niazi, 2008). Since the nineties of the last century, software companies have assessed the capability of their processes according to MMs such as CMM, CMMI, and ISO/IEC 15504, at the diagnosing phase in the SPI initiative (Fe, 2008; Staples & Niazi, 2008). Diverse proposals can be found which are geared at enhancing maturity of process in diverse disciplines and domain areas (Anderson, Watson, & Armstrong, 1982). The idea of capability or process maturity is therefore fundamental in SPI initiatives. To García-mireles (2012), this idea has been the springboard from which MM have been developed to assist organizations to enhance software quality. These organizations are concerned with the establishment of standard operation norms and criteria to improve processes. In the software engineering domain, the models are in search of organizational maturity, defined as the capability of an organization to implement, establish, standardize, measure and improve software processes.

According to Cooke-Davies (2007) there is no common and generally accepted definition of what a "mature project-based organization" looks like. For Mettler (2011), maturity is a measurement of the ability of an organization for continuous improvement in a particular discipline and, as a measure to evaluate the capabilities of an organization in regards to a certain discipline, has become popular since the Capability Maturity Model (CMM) has been proposed by the Software Engineering Institute at Carnegie Mellon University. Whilst the original CMM has a specific focus on the evaluation of SD processes, this model has been varied and extended in several approaches and is now applied for the evaluation of IT Infrastructure Management, Enterprise Architecture Management and Knowledge Management to name a few. CMM is now one of the best and most widespread models today is the Capability Maturity Model Integration (CMMI), which, in five stages, provides sequences for improvement as well as a basis to assess the deployment maturity of specific projects or organizations (Verrier, Rose, & Caillaud, 2016).

MM's are commonly used as an instrument to conceptualize and measure maturity of an organization or a process regarding some specific target state (Schumacher, Erol, &

Sihn, 2016). Further, MM intended for a prescriptive purpose of use include good or best practices which is helpful to provide practical guidance (Maximilian & Schwindenhammer, 2018). They refer that maturity not only implies a potential for growth in capability, but also focuses on richness and consistency regarding execution. In this regard Andersen & Jessen (2003) define maturity as the quality or state of being mature. The maturity concept must be related to a state in which organizations are in perfect conditions to achieve their goals (Berssaneti, Carvalho, & Muscat, 2012).

The higher the maturity, the higher will be the chances that incidents or error correction will lead to improvements either in the quality or in the use of the resources of the discipline as implemented by the organization. Most MMs assess qualitatively people/culture, processes/structures, and objects/technology (Mettler, 2011).

These MMs are an interesting approach to solving the problem described in Section 1.1., regarding the lack of knowledge about DevOps, since the presence of a maturity classification provides a roadmap for process improvement and allows the comparison between organizations to encourage competition and differentiation.

Two approaches for implementing MMs exist. With a top-down approach, such as proposed by Becker et al. (2009) a fixed number of maturity stages or levels is specified first and further corroborated with characteristics (typically in form of specific assessment items) that support the initial assumptions about how maturity evolves. On the other hand, when using a bottom-up approach, such as suggested by Lahrmann, Marx, Mettler, Winter, & Wortmann (2011), distinct characteristics or assessment items are determined first and clustered in a second step into maturity levels to induce a more general view of the different steps of maturity evolution. This research follows the top-down MM approach proposed by Becker et al. (2009).

2.3.CMMI

CMMI (and its predecessor CMM) is a framework intended to cover many software engineering best practices and can be used for SPI. CMMI is most well known in its “staged” representation, which has five maturity levels. To reach a maturity level, a company must satisfy the goals of the process areas for that and all lower levels. The expected capacity of an organization that operates in a more mature way depends directly on your ability to perform, control, and improve performance in one or more areas of implementation of the model practices (Barbosa, Furtado, & Gomes, 2007).

CMMI evokes barriers in some because of the processes involved in certification. However, CMMI at its core is not a methodology but rather a set of principles. In the case of CMMI, the set of principles focuses on maturation of a SD process. This is an emphasis which is quite differentiated from the Agile approach. CMMI is concerned with defining metrics and practices to ensure continuous improvement (Chrissis, Konrad, & Shrum, 2010). The goal of CMMI is not just to support a minimum set of standards to achieve to a particular level, but to enable increasing improvement in organizational processes. CMMI's approach is based on MM. It supports both a staged approach and a continuous model for improvement. It provides several key process areas at different levels. The key process areas are intended to help gauge where an organization is at in the maturation process as well as provide guidance for how to achieve the desired level. CMMI associates skill in different process areas with higher maturity levels. Maturity levels are those that are related to the path which helps organizations to apply improvements to a set of related processes by incrementally addressing successive sets of process areas and goes through 1 to 5 as follows:

- **Level 1: Initial –** There is no formal process.
- **Level 2: Managed –** There is a minimal process and the status of projects is visible to management at major milestones
- **Level 3: Defined –** Processes are well characterized and understood, and are described in standards, procedures, tools, and methods.
- **Level 4: Quantitatively Managed –** The organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managing processes
- **Level 5: Optimizing –** All processes are already defined and managed. Goals for levels one to four are all achieve.

Chapter 3 – Related Work

This section intends to describe the main contributions of the scientific community in DevOps maturity. Since this research aims to study DevOps' maturity, it is mandatory to search literature where it is possible to study other proposals for DevOps' MMs. However, given that DevOps is a new term and concept recently introduced, the author decided to extend the scope of the study to SD MMs. To do that, the author performed a literature review.

A literature review may be helpful distinguishing what has been done from what needs to be done, discovering important variables relevant to the topic, synthesizing and gaining a new perspective or identifying relationships between ideas and practice (Hart, 1998). An effective review creates a solid foundation for advancing knowledge. It facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed (Webster & Watson, 2002). For easier understanding of the peers, as well as to add more scientific rigor to our research, the author decided to follow the concept centric approach proposed by Webster & Watson(2002).

To perform the literature, review the researcher have searched and consulted the following digital repositories: IEEExplore, ACM, Research Gate and it was also used the search engine of Google Scholar.

This research was carried out between September of 2018 and January of 2019. The keywords used to perform this research were: "DevOps maturity model", "DevOps maturity", "Software Development Projects maturity model", "Software development projects maturity", "Scrum maturity model" and "Scrum maturity".

In this section, the main findings regarding SDP, Scrum and DevOps MMs are presented (Table 1). Table 2 intends to give a perspective about this studies characteristic, while Table 3 contains all the studies mapped with the corresponding maturity vectors found by the researcher in the proposed MMs. These three tables are expected to clarify the existing related work on this area and related domains.

Since DevOps is a recent theme and there are not a lot of dedicated maturity studies in literature (Rong, Zhang, & Shao, 2016a). The researcher has decided to include agile and scrum MMs.

Both Scrum and DevOps have in common to broaden the usage of Agile practices to operations to streamline the entire software delivery process in a holistic way

(Hüttermann, 2012; Bang, Chung, Choh, & Dupuis, 2013). Table 1 presents all the MMs for SDP, Scrum and DevOps found among the literature.

Table 1 - SDP, and DevOps MMs

ID	Author	MMs			Model	Maturity Levels	Dimension
		DevOps	Scrum	SDP			
S.1	(Mohamed, 2015)	X			*CMMI*	*5*	*4*
S.2	(Bucena & Kirikova, 2017)	X			*Not defined*	*5*	*4*
S.3	(A. P. G. Yin, 2011)		X		*CMMI*	*5*	*Not defined*
S.4	(Srivastava, Bhardwaj, & Saraswat, 2017)		X		*Not defined*		*Not defined*
S.5	(Kawamoto & De Almeida, 2017)		X		*CMMI*	*Not defined*	*Not defined*
S.6	(Baskarada, Gao, & Koronios, 2005)			X	*CMMI*	*5*	*Not defined*
S.7	(Patel & Ramachandran, 2009)			X	*CMMI*	*5*	*Not defined*
S.8	(Buglione, 2011)			X	*CMMI*	*5*	*4*
S.9	(Santana, Soares, Romero De, & Meira, 2013)			X	*CMMI*	*5*	*Not defined*
S.10	(Fontana, Meyer, Reinehr, & Malucelli, 2015)			X	*CMMI*	*Not defined*	*6*
S.11	(Stojanov, Turetken, & Trienekens, 2015)			X	*Not defined*	*5*	*5*

From the analysis of Table 1 some conclusions can be withdrawn. The low number of DevOps MMs that has been found indicate that few studies exist deep studying DevOps. The number of studies on SDP is greater than for scrum and DevOps. One of the main reasons for this is that most of the SDP uses Agile methodology, which in turn is the basis for both DevOps and Scrum so it is expected that there exist more studies about this theme than for the others.

CMMI seems to be the basis of these models since it was used in 73% of these studies. It was not explicit any of the vectors that constitutes the Scrum' MMs and, apart from one study, the same happened to the number of levels used. This is justified by the fact that CMMI is a well-known methodology used to develop and refine an organization's SD process (Farkas & Walsh, 2002). CMMI is an approach to improve processes that provides elements that are essential for an effective process. It brings together best practices that address development and maintenance activities, thus covering the entire lifecycle of a product from conception to delivery and maintenance (Chrissis et al., 2010). It has been also included a vector named "Dimension" that represents the number of

vectors that were represented in model. From the previous table, it is possible to see that the study with less dimensions had four and on the opposite side, the study with more dimensions has six. This helps the researcher to put into perspective the number of dimensions used in other MM, to understand the number of dimensions that should be used in this study.

Mohamed (2015) built a DevOps MM based on CMMI with five maturity levels. More concretely, the model comprises an initial, managed, defined, measured, and optimized level that denote an increase in maturity with respect to four dimensions, which are known as communication, automation, governance, and quality management.

Bucena & Kirikova (2017) also proposed a MM for DevOps. Although the researcher did not used the CMMI approach, the presented model also have 5 levels of maturity. These five levels of maturity relate to four enterprise areas, namely, technology, process, people, and culture. For each chunk in the MM, corresponding DevOps practices reported by DevOps practitioners were associated. Bucena & Kirikova (2017) developed this model as an attempt to facilitate the adoption of DevOps in small enterprises. The experimental application of this model was done in the IT department of a medium sized enterprise where Its main business is not related to IT, where Bucena & Kirikova (2017) considered the department with twenty one IT department employees as a small enterprise.

There are other studies among the literature that, although not presenting any MM, indicate a creation of a CMMI based MM for DevOps. For Rong et al. (2016), it is important to mature adoption of the DevOps for software companies, no dedicated MMs for DevOps exist. On Rong et al. (2016) study, the authors reports a case study with a real-world project, which sheds light on the adoption status of the DevOps in a project in its early stage of transition from products delivery to services deployment and maintenance. Furthermore, the results of his study reveal that the CMMI models could provide a good foundation to extend the models.

To obtain a clearer view about the characteristics of the studies of the MM which have been found, the researcher has constructed the following table (Table 2). In this table, vectors have been used to that help for a better understanding of the characteristics of these studies, such as the year in which the model was developed, which MM was based on, if it follows Becker's top-down approach, if the author justified the vectors used, whether they comply with the Design Science Research (DSR) steps and if any demonstration of the model was made.

Table 2 - MMs characteristics

ID	Year	Proposed MM	Based MM	Becker's top-down approach	Vectors validation	DSR	Demonstration
S.1	*2015*	*DevOps*	*CMMI*	*Not used*	*Not validated*	*Not used*	*Not applied*
S.2	*2017*	*DevOps*	*Not defined*	*Not used*	*Validated*	*Not used*	*Applied*
S.3	*2011*	*Scrum*	*CMMI*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.4	*2017*	*Scrum*	*Not defined*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.5	*2017*	*Scrum*	*CMMI*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.6	*2005*	*SDP*	*CMMI*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.7	*2009*	*SDP*	*CMMI*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.8	*2011*	*SDP*	*CMMI*	*Not used*	*Not Validated*	*Not used*	*Applied*
S.9	*2013*	*SDP*	*CMMI*	*Not used*	*Not defined*	*Not used*	*Not applied*
S.10	*2015*	*SDP*	*Not defined*	*Not used*	*Validated*	*Not used*	*Applied*
S.11	*2015*	*SDP*	*CMMI*	*Not used*	*Validated*	*Not used*	*Not applied*

Overall, two MMs for DevOps were identified in literature. However, as one can see in Table 2, both MMs lack the use of structured methods in the design process which may raise doubts on the rigor of the MMs. For instance, only one is based on CMMI and none adopts Becker theory or DSR.

Table 3 intends to list and synthesize the related work and identify what vectors were used on the MM which have been found. By doing it, the researcher aimed to identify the main vectors that were applied on those case studies and understand the reasons behind those.

For a better understanding, the studies have been grouped by approach. A vector can be written on a different way depending on its context, so the researcher has grouped these vectors by the meaning of the vector. Table 3 shows the vectors grouped by study.

Table 3 - Vectors used in the MMs from related work

Vector	DevOps		Scrum			Agile					
	S.1	S.2	S.3	S.4	S.5	S.6	S.7	S.8	S.9	S.10	S.11
Culture		X									
Collaboration	X									X	
Process		X									
Quality	X										
Automation	X										
Governance	X										
Technology		X									
People		X								X	X
General								X			
Sustained Success								X			
Organization's Environment								X			
Interested parties, needs and expectations								X			
Embrace Change to Deliver Customer Value										X	
Plan and Deliver Software Frequently										X	
Technical Excellence										X	
Practices											X
Deliveries											X
Requirements											X
Product											X
Customer											X

Through the analysis of Table 3, it can be devised that several MM exist in the literature. In six of these studies, the authors did not specify the vectors that would be used. Although DevOps studies are less than agile studies, some agile MMs use the same vectors defined by the DevOps MMs. This may be due to the fact that, first, DevOps and agile keep a close relationship and, secondly, DevOps is a recent topic and there is not much information available about it (Hussain, Clear, & MacDonell, 2017). On agile studies, with some exceptions, it appears that each author defined most of their vectors.

Focusing on DevOps studies, there are no common characteristics present among the two models found. This also proves that the field needs further developments to reach more consensus and completeness. Each author decided to establish their own vectors based on what they thought best defines the characteristics and that could help define the maturity of DevOps in the context of their studies.

To Mohamed (2015), the keys to successful adoption of DevOps are quality, automation, collaboration, and governance/process, while claiming that, together, these fundamental elements can unify the traditional IT silos to enable agility across the end-to-end application life cycle. On the other hand, Bucena & Kirikova (2017) DevOps MM was developed on the basis of analysis of related work and includes five levels of maturity with respect to the four enterprise areas, namely, technology, process, people, and culture. No surprises with the absence of DevOps as possible vectors to assess DevOps maturity.

With the lack of consensus among the studies as well as the absence of both the use of rigorous methods/methodologies in the design process and DevOps capabilities as vectors of maturity assessment, the design of a new MM for DevOps can be faced as an opportunity and a step forward on the perspective of associated mature practices.

Chapter 4 – Research Methodology

4.1.Design Science Research

For the development of the proposed DevOps MM, it was applied the design science research methodology (DSRM) presented by Peffers et al. (2006) and the seven guidelines for DSR proposed by Hevner, March, Park, & Ram (2004). DSR approach was selected since this research aims at solving practical problems by creating and evaluating IT artifacts intended to solve identified organizational problems (Hevner et al., 2004).

IT artifacts are broadly defined as constructs (i.e., vocabulary and symbols), models (i.e., abstractions and representations), methods (i.e., algorithms and practices), and instantiations (i.e., implemented and prototype systems) (Hevner et al., 2004). According to Becker et al. (2009) and Mettler (2009), it can be assumed that the development of MMs falls within the application area for the guidelines by Hevner et al (2004). and accordingly, DSR.

According to Peffers et al. (2006), the DSRM consists of six activities (i.e. steps). Figure 1 presents our applied techniques and performed activities in each DSRM step. In order to achieve rigorous as well as relevant research results, it was drawn upon the following DSRM steps, whereby the paper is structured accordingly:

- **Problem identification and motivation:** In the first chapter, it was specified the problem, provided practical relevance and justified the value of a solution. Additionally, based on problem scope, research questions were derived guiding this research.
- **Define the objectives for a solution:** The second chapter provides objectives of the intended collaboration MM. Based on a literature review, design recommendations in MM design and assessment will be identified and suggestions for circumvention will be proposed.
- **Design and Development:** This activity is present in Chapter 5 and describes the MM development. Based on a literature review the MM will be designed and iteratively developed according to the requirements of MM construction (Becker et al., 2009).
- **Demonstration:** By means of an application test with three participant organizations the applicability and usability of the artifact was demonstrated. The utility of the MM will be further validated DevOps experts.

- **Evaluation:** According to Hevner et al. (2004), the artifact will be evaluated in terms of quality, utility and efficacy which cannot be demonstrated fully in this research.
- **Communication**: Communicate the problem, the importance, the utility, the rigor and the effectiveness of its design.

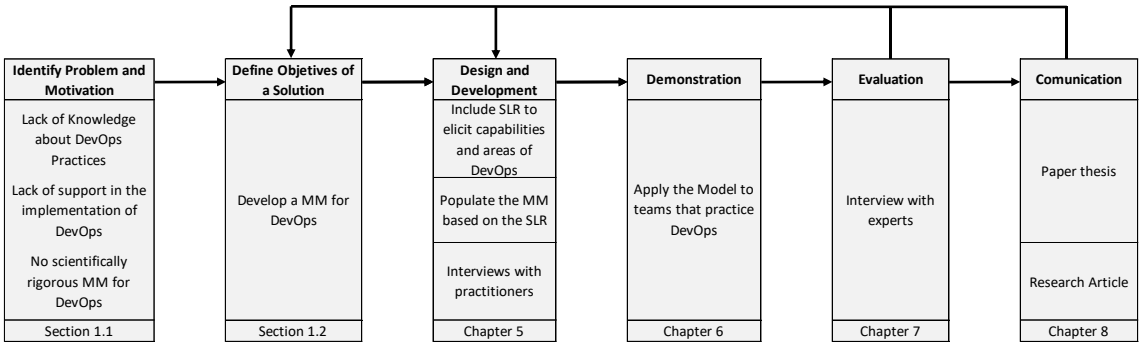

Figure 1 - Applied DSR guidelines

4.2.Systematic Literature Review

One of the major tools used in other domains to support an evidence-based paradigm is the generation of Systematic Literature Reviews (SLR), which is used to aggregate the experiences gained from a range of different studies in order to answer a specific research question (Khan, Kunz, Kleijnen, & Antes, 2004).

A SLR is a literature review method that aims to address a problem by identifying, evaluating, integrating all relevant findings, and interpreting research on research topics to answer research questions based on the stages used in SLR (Siddaway, 2014). The process of addressing the problem of lack of knowledge aims to identify the relationships and gaps in the existing literature. The identification process is used to describe directions for future research, because it consists of the process of formulating a general statement or an overarching conceptualization, commenting on, evaluating, extending, or developing theory from existing literature (Siddaway, 2014).

This research follows Kitchenhams Procedures for SLR (Kitchenham, 2004), complemented by the centric approach from Webster and Watson (Webster & Watson, 2002), which encompass the following steps:

- **Planning.** It is necessary to confirm the need for such a review. It is also necessary to define the research question(s) that the systematic review will address and produce a review protocol (i.e. plan) which defines the basic review procedures.
- **Conducting.** Apply the review protocol previously designed in order to obtain studies which will be the object of the review.
- **Reporting.** The final phase of a systematic review, which involves writing up the results of the review and circulating these results to potentially interested parties.

4.3.Semi-structured Individual Interviews and Email Interviews

The interview study reported here was carried out with DevOps practitioners Professionals from all over the world. The study took place as a qualitative interview study in the tradition of the qualitative research interview, which allows the researcher to ask questions to different issues in the interviewees' life-world, including practical issues of how to do things and cognitive issues such as personal and professional epistemologies (Kvale, 1996).

Before conducting an interview, it is important for the researcher to have a thorough preparation to help in screening potential individuals who will be used as participants and it may be helpful in gaining preliminary ideas and important information about the topic and individuals to be interviewed. In this study, participants were provided with background information and an overview of the topics prior to its discussion.

One-to-one (or individual) interviews are as old as mankind and had already been used by the Ancient Egyptians for demographic investigations (Fontana and Frey, 1994). For individual interviews to be used as a research method, one of the participants should act as a researcher, and conduct the interview with the objective to answer a research question. Individual interviews can take a large variety of formats, ranging from structured (or close-ended) to unstructured (or ethnographic): While the first gives little room for variation in the answers (Fontana and Frey, 1994) the latter is closer to observation and leads to open-ended data (Fielding & Maanen, 1989). Between these two extremes, semi-structured interviews allow for long and in-depth accounts, while also providing guidance on the interview topic.

There are several advantages of one-to-one, face-to-face interviews. First, qualitative interviewing enables the researcher to gain deep insights into the respondents' perspectives (Liguori, Selltiz, Jahoda, Deutsch, & Cook, 2007). Second, qualitative interviews are relatively inexpensive and allow collection of very rich data, enabling the

researcher to notice and correct the respondents' misunderstandings, to probe vague answers, as well as to clarify doubts or concerns. Compared to other research methods, face-to-face interviews allow to monitor the order in which the questions are answered, and to control the context of the interview, thereby avoiding the possible biasing presence of other people (Liguori et al., 2007). Finally, the interviewing methodology is easily adjustable and can be combined with quantitative methods.

Semi-structured interviews are characterized by the use of a script consisting of closed or open predefined questions (Rijo, 2008). They are suitable when the research wants to validate several hypotheses but also to know the fieldwork and to explore new ones (Pozzebon, 2006). Particularly, they enable the interviewee to discuss the subject matter without being too attached to the formulated inquiry (Manzini, 2004). They also facilitate the interviewer to have clear support following the questions (Manzini, 2004). Moreover, they ensure to researchers that their hypotheses or assumptions will be broadly covered by the conversation (Minayo, 2004).

Qualitative research has become essential to the humanities over the past twenty years (Ratislavová & Ratislav, 2014). During that time, researchers have identified weaknesses in the qualitative approach, such as the fact that it is very time consuming, difficult to access, and expensive. Synchronous and asynchronous interviews and virtual focus groups are the most common methods (Ratislavová & Ratislav, 2014). The use of Email Interview can be employed quickly, conveniently, and inexpensively and can generate high-quality data when handled carefully. Although the method has a number of challenges, many of them were found to be easy to overcome, presenting scholars with a new technique for conducting efficient and effective qualitative research. While a mixed mode interviewing strategy should always be considered when possible, semi-structured e-mail interviewing can be a viable alternative to the face-to-face and telephone interviews, especially when time, financial constraints, or geographical boundaries are barriers to an investigation (Meho, 2006).

Chapter 5 – Design and Development

To design the artifact, the author followed the steps listed below:

Step 1: Identify which are the main DevOps capabilities

Method(ology): SLR

Step 2: Identify which are the areas that most relate with DevOps.

Method(ology): SLR

Step 3: Identify the main practices of each DevOps capability

Method(ology): Literature Review

Step 4: Identify the maturity level of each DevOps practice

Method(ology): Interview

For a better understanding of the Design and Development's phase, the researcher built the workflow (Figure 2) of the four previously described steps.

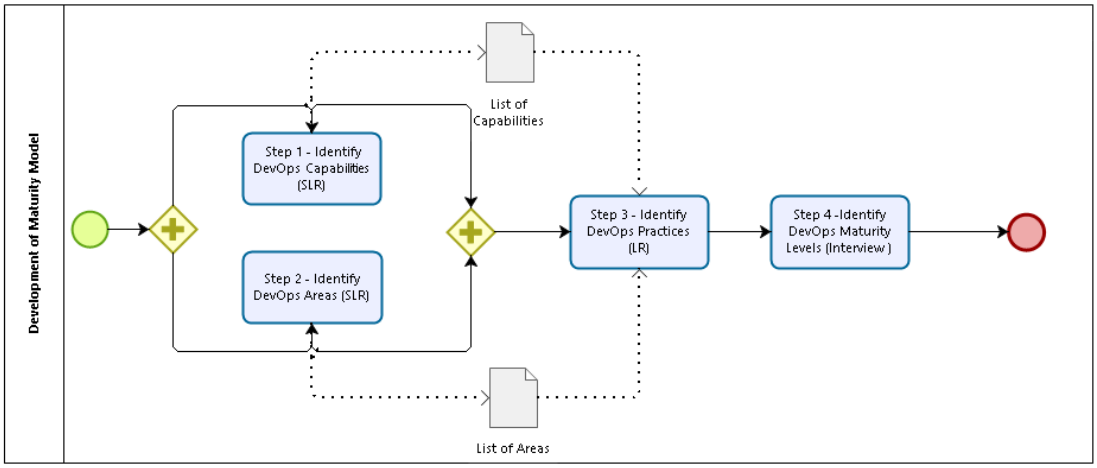

Figure 2 - Workflow of the Design and Development's phase

5.1.Step 1 (Capabilities)

Figure 3 details the SLR phases adopted in Step 1. The SLR was chosen as a starting point to develop our Research Methodology to summarize the existing evidence regarding DevOps' capabilities, with the aim of answering the proposed Research Objectives.

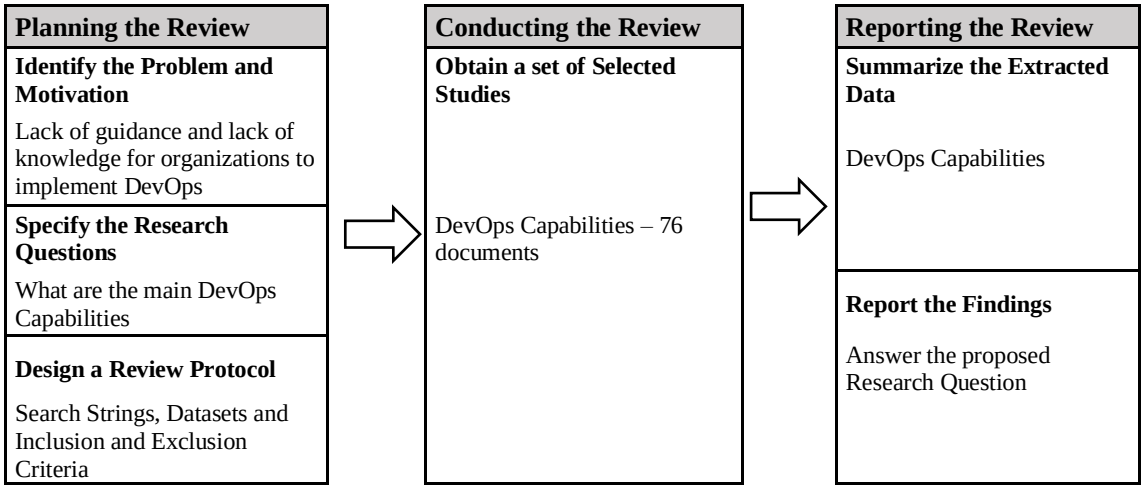

Figure 3 - SLR Methodology for DevOps' capabilities

5.1.1. Review protocol

The review protocol starts with a literature search, with the definition of the search string that will be used in the chosen datasets in order to retrieve the maximum number of studies that may address the proposed research questions. The search string which was used and respective datasets are listed below.

Search String:

For DevOps capabilities. *DevOps AND (Capability OR Capabilities OR Practice)*

Datasets: Google Scholar, ScienceDirect, IEEEXplore, ACM.

After that, inclusion and exclusion criteria must be applied to filter the obtained documents. Our criteria are presented in Table 4.

Table 4 - Inclusion and Exclusion Criteria for DevOps' Capabilities

Inclusion Criteria	Exclusion Criteria
Written in English or Portuguese	*Not written in English or Portuguese*
Scientific papers in conferences or journals and books	*Non-Free documents nor Master Thesis*
Title relevance regarding DevOps	*No title relevance DevOps*

Afterwards, the first set of documents is obtained. Then, in a first phase, the abstracts must be screened to decide their relevance to the research. Finally, these documents are read in order to obtain the final selection of studies to perform the review. The review protocol is illustrated in Figure 4.

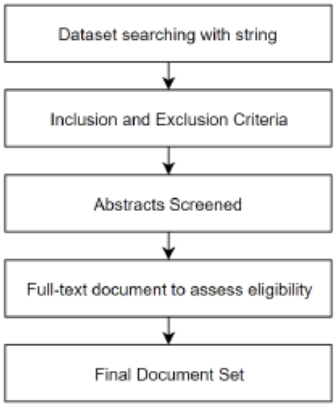

Figure 4 - Review Protocol for DevOps' Capabilities

For a better understanding, as well as to add more scientific rigor to the research, the researcher decided to follow the centric approach proposed by Webster and Watson (Webster & Watson, 2002).

5.1.2. Conducting the Review

This section corresponds to the second step of the SLR Methodology. It has been started by applying the review protocol previously defined and perform an analysis of the extracted data.

5.1.2.1 Selection of Studies

After applying the relevant search string in the listed datasets, with the inclusion and exclusion criteria presented in Figure 5, 112 papers were obtained, excluding duplicates.

Afterwards, the abstracts were read to further determine the documents' relevance. This resulted in 82 documents, which were, in turn, individually read. As a result of this process, 76 relevant studies were obtained for our research.

Figure 5 shows the number of papers found. As it shows in Figure 5, the search which has been conducted aims to find all papers in which DevOps capabilities has been mentioned.

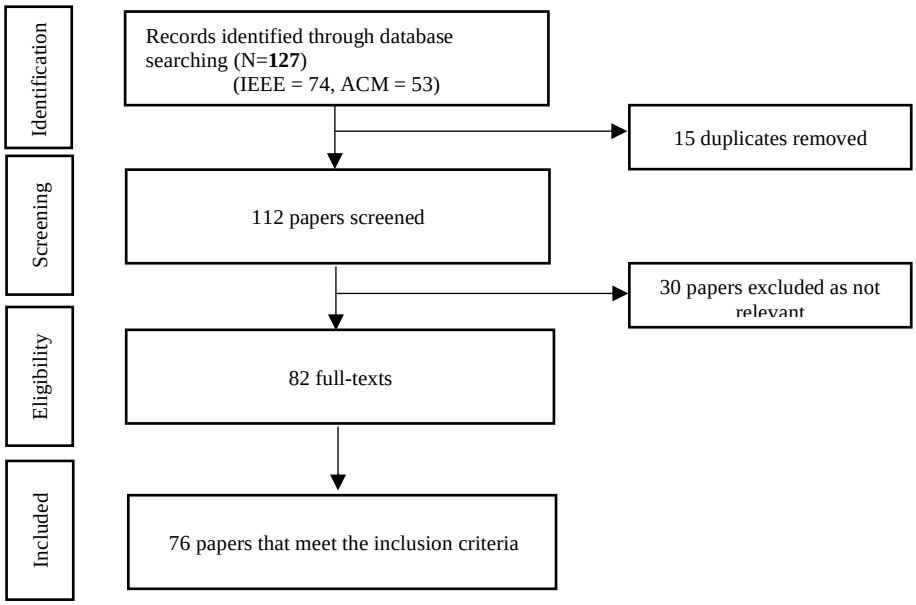

Figure 5 - Search strings, databases used and results from search conducted for DevOps capabilities

5.1.2.2 Data Extraction Analysis

Through the analysis of Figure 6 it is possible to see the distribution over the years of the articles which deal with DevOps capabilities. In 2011, only two capabilities were related with DevOps. Since then, there has been an increase in the number of documents and capabilities. This can be explained by the fact that DevOps gained popularity and the increase of interest over time would be expected, this is reflected on the number of publishes articles. Since 2015, the quantity of documents rose slightly and in 2016 interest grew exponentially.

It is also possible to see that the interest in CI and Continuous Deployment (CD) documents has remained above the interest in the remaining capabilities over the years.

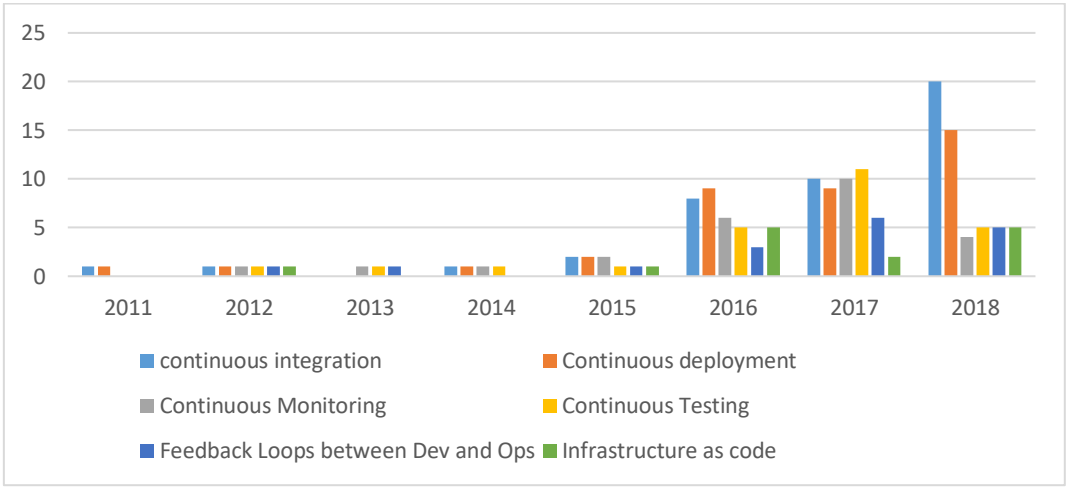

Figure 6 - DevOps Capabilities Articles Distribution per year

5.1.3. Reporting the Review

This section corresponds to the third and last step of the SLR Methodology, where it was summarized the extracted data from the selected studies. It was identified one main topic, which integrate this section: DevOps Capabilities.

A recent study was published (Jabbari, bin Ali, Petersen, & Tanveer, 2016) where the authors have synthesized the practices that DevOps practitioners have applied so far (Table 2). Since this study seems to be complete and the author did not find a single DevOps' practice that was not included in Jabbari's list, the author decided to use this list assuming that is the most completed collection of DevOps practices among the literature. Other studies related to DevOps capabilities can be found among the literature - in Hüttermann (2012); Sharma (2017a), Punjabi and Bajaj (2017), Soni (2016), and Stoneham et al. (2017). However, they are not as exhaustive as the one presented in Figure 6.

Within these studies, a capability can be described in a different way, depending on its context, but maintain the same meaning. As such, the researcher has grouped these capabilities together by using vectors and basing such groupings on what they have understood of the meaning of the capability. Table 5 shows the grouping that the author made for these vectors. Although the study was already quite complete, the author decide to carry out a literature review that could corroborate these abilities presented in the study of Jabbari et al. (2016a).

Having analyzed Table 5, and observing that there is a considerable gap between C6 and C7, the researcher has decided to describe all the capabilities from C1 and C6. The description of each capacity is presented considering the various definitions which have been found.

5.1.3.1 Continuous Integration

The CI concept was first practiced and described as "doing everything in parallel, with frequent synchronizations" in the 1998 book *Microsoft Secrets* (Pang & Hindle, 2017). CI consists of established practices in modern agile SD (Steffens, Lichter, & Döring, 2018a). It accommodates rapid changes (Bai, Li, Pei, Li, & Ye, 2018) and is widely considered to be the best in SD (Debroy, Miller, & Brimble, 2018).

Table 5 - DevOps capabilities SLR

ID	Capabilities	Reference	# of References
C1	*Continuous Integration*	(Bai et al., 2018; Bucena & Kirikova, 2017; H. M. Chen, Kazman, Haziyev, Kropov, & Chtchourov, 2015; Cleveland et al., 2018; Colomo-Palacios et al., 2018; Croker & Hering, 2016; De Bayser et al., 2015; de França et al., 2016; Debois, 2011; Debroy et al., 2018; Düllmann et al., 2018; Fitzgerald & Stol, 2014; Hüttermann, 2012; Jabbari et al., 2016; Kuusinen et al., 2018; Laukkarinen, Kuusinen, & Mikkonen, 2017, 2018; Lewerentz et al., 2018; Mackey, 2018; Mansfield-Devine, 2018; Marijan, Liaaen, & Sen, 2018; Mohan & Ben Othmane, 2016; Molto, Caballer, Perez, Alfonso, & Blanquer, 2017; Moore et al., 2016; Palihawadana et al., 2017; Pang & Hindle, 2017; Punjabi & Bajaj, 2017; Rahman, Mahdavi-Hezaveh, & Williams, 2018; Rodríguez et al., 2018; I. D. Rubasinghe et al., 2017; I. Rubasinghe, Meedeniya, Perera, & Practice, 2018; Shahin, Babar, & Zhu, 2016; Sharma, 2017a; Shivakumar, 2017; Snyder & Curtis, 2017; Soni, 2016; Steffens et al., 2018a; Stoneham et al., 2016; Tuma et al., 2018; Vassallo et al., 2017; Wiesche, 2018; Wongkampoo & Kiattisin, 2018; Xia, Zhang, Wang, Coleman, & Liu, 2018; Yin, Zhang, & Wang, 2004; H. Zhu & Bayley, 2018)	*44*
C2	*Continuous Deployment*	(Ali, Caputo, & Lawless, 2017; Bass, 2017; Bhattacharjee, Barve, Gokhale, & Kuroda, 2018; Bucena & Kirikova, 2017; H. M. Chen et al., 2015; Cleveland et al., 2018; Debois, 2011; Debroy et al., 2018; Düllmann et al., 2018; Farshchi, Schneider, Weber, & Grundy, 2015; Fitzgerald & Stol, 2014; Fördős & Cesarini, 2016; Hüttermann, 2012; Jabbari et al., 2016; Karapantelakis et al., 2016; Kuusinen et al., 2018; Laukkarinen et al., 2018; Mackey, 2018; Mansfield-Devine, 2018; Mohan & Ben Othmane, 2016; Palihawadana et al., 2017; Pang & Hindle, 2017; Perera, Bandara, & Perera, 2017; Punjabi & Bajaj, 2017; Rahman et al., 2018; Rana & Staron, 2016; I. D. Rubasinghe et al., 2017; I. Rubasinghe et al., 2018; Shahin et al., 2016; Sharma, 2017a; Shivakumar, 2017; Soni, 2016; Steffens et al., 2018a; Steffens, Lichter, & Döring, 2018b; Stoneham et al., 2016; Tuma et al., 2018; Ur Rahman & Williams, 2016b; Wiesche, 2018; Xia et al., 2018; Yin et al., 2004; H. Zhu & Bayley, 2018)	*39*
C3	*Continuous Monitoring*	(Bai et al., 2018; Bucena & Kirikova, 2017; H. M. Chen et al., 2015; de França et al., 2016; Düllmann et al., 2018; Fitzgerald & Stol, 2014; Hanappi, Hummer, & Dustdar, 2016; Hüttermann, 2012; John et al., 2015; Karapantelakis et al., 2016; Kuusinen et al., 2018; Li, Zhang, & Liu, 2017; Pang & Hindle, 2017; Perera, Bandara, et al., 2017; Rana & Staron, 2016; Roche, 2013; I. D. Rubasinghe et al., 2017; Rufino, Alam, & Ferreira, 2017; Sharma, 2017a; Shivakumar, 2017; Snyder & Curtis, 2017; Soni, 2016; Steffens et al., 2018b; Ur Rahman & Williams, 2016b; Vassallo et al., 2017; Yin et al., 2004)	*25*
C4	*Continuous Testing*	(Bucena & Kirikova, 2017; H. M. Chen et al., 2015; Croker & Hering, 2016; de Feijter, Rob, Jagroep, Overbeek, & Brinkkemper, 2017; Fitzgerald & Stol, 2014; Hüttermann, 2012; Jabbari et al., 2016; Kuusinen et al., 2018; Murugesan, 2017; Nielsen et al., 2017; Palihawadana et al., 2017; Pang & Hindle, 2017; Punjabi & Bajaj, 2017; Roche, 2013; I. Rubasinghe et al., 2018; Samarawickrama & Perera, 2018; Shahin et al., 2016; Sharma, 2017a; Shivakumar, 2017; M. M. A. Silva et al., 2018; Snyder & Curtis, 2017; Soni, 2016; St et al., 2017; Stoneham et al., 2016; Vassallo et al., 2017; Wiesche, 2018; Yin et al., 2004)	*26*
C5	*Feedback Loops between Dev and Ops*	(Bucena & Kirikova, 2017; de Feijter et al., 2017; Debroy et al., 2018; Hanappi et al., 2016; Hüttermann, 2012; Jabbari et al., 2016; John et al., 2015; Kuusinen et al., 2018; Mikkonen, Lassenius, Männistö, Oivo, & Järvinen, 2018; Murugesan, 2017; Nielsen et al., 2017; Pang & Hindle, 2017; Roche, 2013; Sharma, 2017a; M. M. A. Silva et al., 2018; St et al., 2017; Stoneham et al., 2016; Wongkampoo & Kiattisin, 2018; Yin et al., 2004)	*18*
C6	*Infrastructure as code*	(Bhattacharjee et al., 2018; Bucena & Kirikova, 2017; De Bayser et al., 2015; de França et al., 2016; Debroy et al., 2018; Düllmann et al., 2018; Fördős & Cesarini, 2016; Hüttermann, 2012; Jabbari et al., 2016; Jimenez et al., 2017; Rahman et al., 2018; Rana & Staron, 2016; Shahin et al., 2016; Sharma, 2017a; Steffens et al., 2018b, 2018a; Yin et al., 2004)	*15*
C7	*Change Management*	(Abdelkebir, Maleh, & Belaissaoui, 2017; Debois, 2011; Hüttermann, 2012; Jabbari et al., 2016; Mohamed, 2015; I. D. Rubasinghe et al., 2017; C. Science & Sciences, 2015; Sharma, 2017c; H. Zhu & Bayley, 2018)	*9*
C8	*Continuous planning*	(Fitzgerald & Stol, 2014; Hüttermann, 2012; Jabbari et al., 2016; Kuusinen et al., 2018; Pang & Hindle, 2017; Sharma, 2017c; Ur Rahman & Williams, 2016a)	*7*
C9	*Prototyping application*	(Cleveland et al., 2018; De Bayser et al., 2015; Fitzgerald & Stol, 2014; Hüttermann, 2012; Jabbari et al., 2016; Sharma, 2017c)	*6*
C10	*Process Standardization*	(Hüttermann, 2012; Jabbari et al., 2016; Rana & Staron, 2016; Roche, 2013; Sharma, 2017c)	*5*
C11	*Stakeholder Participation*	(Hüttermann, 2012; Jabbari et al., 2016; Sharma, 2017c)	*3*
C12	*Shift Left*	(de Feijter et al., 2017; Hüttermann, 2012; Sharma, 2017c)	*3*

Developers integrate their work frequently (usually each person integrates at least daily), leading to multiple integrations per day (Jabbari et al., 2016; St et al., 2017). For Sharma and Coyne (2015), CI ensures that each team's work is continuously integrated with that of other development teams and then validated. CI, thereby, reduces risk and identifies issues earlier in the SD life cycle.

Implementing CI this way ensures that bugs are caught earlier in the development cycle, which makes them less expensive to fix. Automated tests are run for every build, in order to ensure that builds maintain a consistent quality. The main objective of CI is to foster discussion and fast validation by peers (De Bayser, Azevedo, & Cerqueira, 2015). As CI allows developers to immediately see the impact of their code changes and fix problems on the spot in the development environment, it became one of the major points of interest in the DevOps movement as smaller and more frequent changes reduced merge and integration issues (Debois, 2011).

5.1.3.2 Continuous Deployment

DevOps emphasizes the use of CD, which means deploying a number of smaller changes as soon as they are released, instead of waiting until a "full package" of changes is ready, and follows directly from the practice of frequent releases (Nielsen et al., 2017)**.** This allows users to benefit from the changes much earlier and developers to see whether their changes work in practice (Feitelson, Frachtenberg, & Beck, 2013). To Düllmann, Paule, & Van Hoorn (2018) one important DevOps practice is the usage of CD as it helps to automate many steps, ranging from a source code commit to the deployment of a software artifact to production. When commonly adopted, CI and CD can cause the SD lifecycle to shorten (Tuma, Calikli, & Scandariato, 2018). For Debois (2011), this capability is just like exercise: "the more you practice deployment to production, the better you will get at it".

The implementation of CD should also reduce the effort required in order to carry out a task. Many of the tasks related to the release of DevOps are being automated, and manual tasks such as configurations are being dealt with automatically. As such, the pool of resources can be released immediately after the task is completed (Kuusinen, Balakumar, Jepsen, & Larsen, 2018). There is a strong relationship between the quality of the software developed and the agility of the organization to the DevOps practices of

SD. Therefore, DevOps practices contribute to the enhancement of these software quality attributes within a CD process (I. D. Rubasinghe, Meedeniya, & Perera, 2017).

5.1.3.3 Continuous Monitoring

Continuous Monitoring collects data and metrics that come from the different stages of the application lifecycle, allowing all involved parties to react quickly in order to improve or modify the functionalities which are being used (Debois, 2011; Sharma & Coyne, 2015). Effective monitoring is essential to allow DevOps teams to deliver at speed, to get feedback from production, and to increase customers' satisfaction, acquisition and retention. By aligning development of monitoring with the development of the whole solution (implementing functional and nonfunctional requirements, building up the application, middleware, infrastructure), they will be able to improve monitoring continuously, to catch gaps in monitoring early, and to ensure that monitoring is always aligned with concrete needs (Hüttermann, 2012).

One of the major contributions is that continuous monitoring may enable early detection of quality-of-service problems, such as performance degradation, and also the fulfillment of service level agreements (Fitzgerald & Stol, 2014).

5.1.3.4 Continuous Testing

Continuous Testing means to test as soon as possible and continuously during the development lifecycle, leading to a development cost reduction as well as to a better software quality. This practice is viable using techniques such as test automation and virtualization, in order to simulate the production environments in which the tests are to be executed and in a scenario that is as realistic as possible (Sharma & Coyne, 2015; Soni, 2016). Also for Sharma and Coyne (2015), continuous testing is known as "shift-left testing", which stresses integrating development and testing activities to ensure that quality is built in as early as possible in the life cycle and nothing is left behind to later instances.

The importance of this capability is that the benefits of Continuous Testing will eventually increase customer satisfaction, as the customer has a larger and more immediate impact on the product. Because the CD pipeline relies heavily on testing, the quality of the system will improve over time, as fewer bugs are introduced into the system

(Kuusinen et al., 2018). This capability also permits a reduction in overall costs, shortens later testing cycles and ensures continuous feedback on quality (Nielsen et al., 2017).

5.1.3.5 Continuous Feedback

The goal of this practice is to get as much feedback as possible in order to perform the necessary corrections. Continuous feedback is developer - focused, which means that feedback relates to coding or architectural problems, build failures, test status and uploads of file releases (L. Zhu et al., 2016).

The new technologies provide the ability to monitor customer behavior, which allows the business team or any other interested parties to take the necessary actions to improve the software (M. M. A. Silva et al., 2018). Monitoring information and user feedback can be used for the purpose of improving the application and thereby enhancing the customer experience (Nielsen et al., 2017).

5.1.3.6 Infrastructure as Code

Infrastructure as code involves fast scaling up and down of infrastructure on demand, treating the configuration code in the same way as the application code (Rana & Staron, 2016). It also emphasizes developing automation logic for deploying, configuring and upgrading software and infrastructure repeatedly and quickly, particularly in a cloud environment (Lwakatare et al., 2015).

Teams avoid manual environmental configuration and enforce consistency through code to represent the desired state of their environments. Deployment of infrastructure as code is repeatable and prevents runtime problems due to configuration drift or lack of dependency. DevOps teams can work with a unified set of practices and tools to deliver applications and infrastructure support quickly, reliably and on a scale. The use of infrastructure as code was recurrently cited as a means of guaranteeing that everyone knows how the execution environment of an application is provided and managed (Luz, Pinto, & Bonifácio, 2018a).

5.2.Step 2 (Areas)

The three SLR phases, described in section 4.1 are represented in Figure 7, and were specifically adapted to this section purpose.

SLR was chosen as Research Methodology since it was intended to summarize the existing evidence regarding DevOps' areas, with the aim of answering the proposed Research Question.

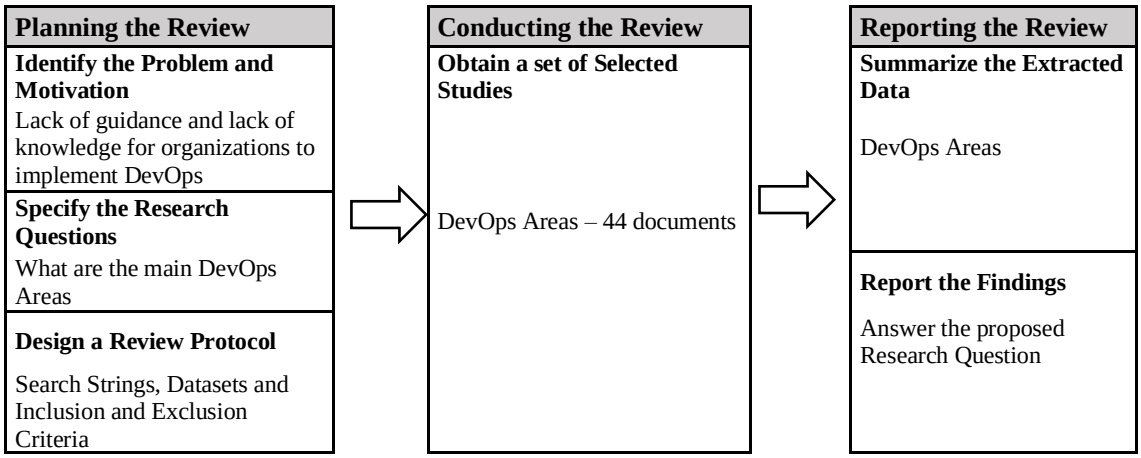

Figure 7 - SLR Methodology for DevOps Areas

5.2.1. Review protocol

The review protocol starts with a literature search, with the definition of the search string that will be used in the chosen datasets in order to retrieve the maximum number of studies that may address the proposed research questions. The search string which was used and respective datasets are listed below.

Search String:

For DevOps Areas. *DevOps AND (Area, Principles, View, Dimensions and Perspective)*

Datasets: Google Scholar, ScienceDirect, IEEEXplore, ACM.

After that, inclusion and exclusion criteria must be applied to filter the obtained documents. Our criteria are presented in Table 6.

Table 6 - Inclusion and Exclusion Criteria for DevOps Areas

Inclusion Criteria	Exclusion Criteria
Written in English or Portuguese	*Not written in English or Portuguese*
Scientific papers in conferences or journals and books	*Non-Free documents nor Master Thesis*
Title relevance regarding DevOps	*No title relevance DevOps*

Afterwards, the first set of documents is obtained. Then, in a first phase, the abstracts must be screened to decide their relevance to the research. Finally, these

documents are read in order to obtain the final selection of studies to perform the review. The review protocol is illustrated in Figure 8.

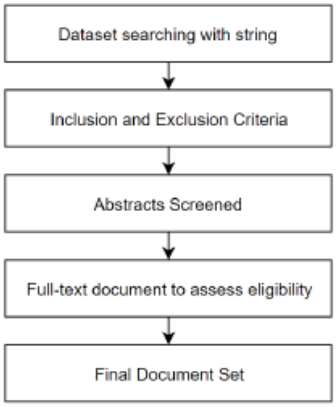

Figure 8 - Review Protocol for DevOps Areas

For a better understanding, as well as to add more scientific rigor to our research, the researcher decided to follow the centric approach proposed by Webster and Watson (Webster & Watson, 2002).

5.2.2. Conducting the Review

This section corresponds to the second step of the SLR Methodology. It starts by applying the review protocol previously defined and performing an analysis of the extracted data.

5.2.2.1 Selection of studies

After applying the needed search string in the listed datasets, with the inclusion and exclusion criteria presented in Figure 9, 82 papers were obtained, excluding duplicates.

Afterwards, the abstracts were read to further decide the documents' relevance. This resulted in 46 documents. Each one of these documents was read and 44 relevant studies were obtained for our research.

Figure 9 shows the number of papers found per database. As depicted, the search conducted aims to find all papers in which DevOps areas have been mentioned.

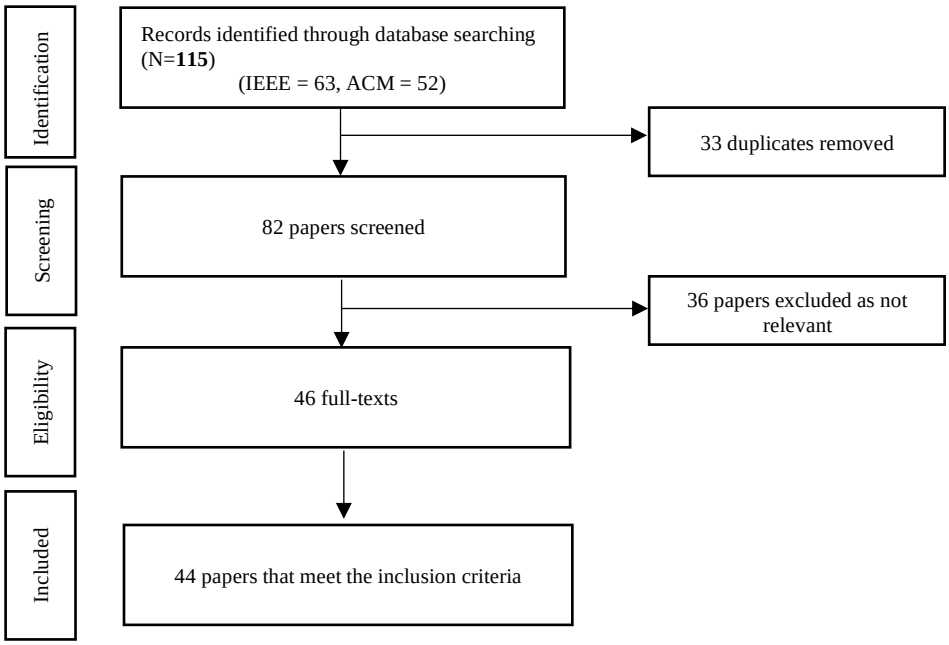

Figure 9 - Search strings, databases used and results from search conducted for DevOps areas

5.2.2.2 Data Extraction Analysis

In order to understand the current importance of the information about DevOps, the author analyzed the dates of the articles regarding this theme. By analyzing at Figure 10, it is possible to observe the distribution of these articles dealing with DevOps areas in the last years. It evidences that interest in DevOps grew in 2015 and in 2016 it grew exponentially. Since then, the level of interest seems to have stabilized. The top area changed in 2018 but Culture is one of the most consistent areas and has generated more interest in recent years.

Measurement, Sharing and Automation have maintained the same level of interest in the past three years, while the interest in Technology, People and Process decreased in 2018 to half of what it was in 2017.

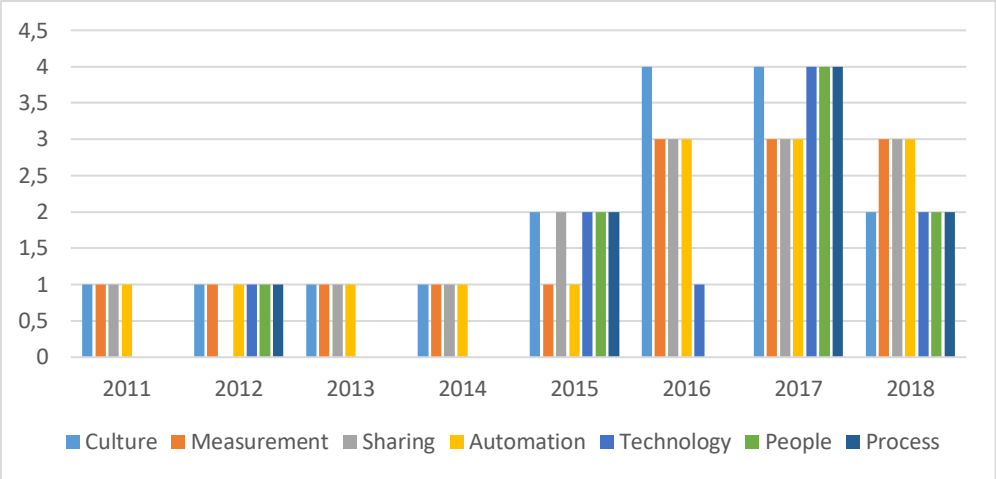

Figure 10 - DevOps Areas Articles Distribution per year

5.2.3. Reporting the Review

This section corresponds to the third and last step of the SLR Methodology, where the data extracted from the selected studies is summarized.

We have identified one main topic, which integrate this section: DevOps Areas. This section presents the findings from a thorough literature analysis aiming to find the DevOps dimensions that characterize this phenomenon. Either they are categories that work as DevOps enablers or are expected outcomes of a DevOps adoption process. Next table (Table 7) presents the main findings related to DevOps dimensions.

Because there is no standard definition of DevOps and its related processes (M. M. A. Silva et al., 2018) and little has thus far been presented in order to describe and formalize what it constitutes (Lwakatare et al., 2015) the author will now go on to detail the areas that best define DevOps practices.

5.2.3.1. Culture

In DevOps, there is a culture of collaboration between the SD organization and the operations organization (Lwakatare et al., 2015) where there is joint responsibility for the delivery of high quality software (Colomo-Palacios et al., 2018). For de França, Jeronimo, and Travassos (2016) the so-called DevOps culture recognizes trust as a relevant characteristic for influencing organizational change. The culture aims to change the dynamics in which development and operational teams interact, highlighting the tasks between design and operation, such as operational design, test-driven development and CI (Diel et al., 2016).

The DevOps culture encourages small, multidisciplinary teams that work independently and collectively to take responsibility for the experience of actual users of their software (Sharma & Coyne, 2015). There is no place like production for a DevOps team. All they do is to improve the live experience of customers. There are no silos and no blame-game, because the team is responsible for each other. DevOps teams stress being able to move fast, understand the impact and react quickly (Hüttermann, 2012).

5.2.3.2. Measurement

The ability to measure the development process by incorporating different metrics will help increase efficiency in product development (Lwakatare et al., 2015). Based on data rather than instinct, decisions lead to an objective and irreproachable path to improvement. The data should be transparent, accessible to everyone, meaningful and capable of being viewed ad hoc. Furthermore, measurement includes monitoring high-level business metrics such as revenue or end-to-end transactions per unit time (Debois, 2011).

At a lower level, it requires careful choice of key performance indicators, since people change their behavior according to how they are measured (Nielsen et al., 2017). DevOps use various forms of measurements and monitoring which include business metrics (e.g. revenue) to metrics for a technical overview (Rana & Staron, 2016).

5.2.3.3. Sharing

Sharing operates at several levels. Information and knowledge are disseminated among individuals to promote the exchange of personal learning and project information. In this sense, individuals should spread relevant information. For instance, information regarding how to implement and perform practices recommended in the context of DevOps (de França et al., 2016). A simple but effective form of sharing is for development and operations teams to celebrate successful releases together (Debois, 2011). It also means sharing knowledge, such as making sure the relevant operations team knows what new functionality is coming their way as soon as possible, and not on the day of the release. Sharing development tools and techniques to manage environments and infrastructure is also a key part of DevOps (Debois, 2011). Sharing concepts contributes to the collaborative culture. For example, all team members gain not only better insight into the entire software production process, but also a solid understanding of shared

responsibilities. A shared vocabulary also emerged from sharing, and this facilitates communication (Luz, Pinto, & Bonifácio, 2018b).

5.2.3.4. Automation

It is believed that manual, and repetitive tasks can be automated to reduce unnecessary effort and improve software delivery. Hence, automation would improve not only the delivery speed, but also the infrastructure consistency, productivity of teams, and repeatability of tasks (de França et al., 2016). Automation is used not just to save time, but it also prevents defects, creates consistency, and enables self-service. Automation is one of the main areas of DevOps: it allows for capabilities such as CI and CD (Mohamed, 2015). Although transparency and sharing can be used to ensure collaboration even in manual tasks, with automation the points where silos may arise are minimized (Luz et al., 2018b).

5.2.3.5. Technology

Technology enables people to focus on high-value creative work while delegating routine tasks to automation. Technology also allows teams of practitioners to leverage and scale their time and abilities (Sharma & Coyne, 2015).

A technology stack and tools are used to quickly and reliably operate and develop applications. These tools also help engineers carry out tasks independently (e.g. code deployment and infrastructure supply), which would normally require the assistance of other teams, and this further increases the speed of the team (Hüttermann, 2012).

5.2.3.6. People

The relations between colleagues should be based on trust and confidence. Transparency should be faced as the rule of thumb for a DevOps team. The members of the team should also have common goals and incentives, and not only developers for delivering in time, with quality new features and operations personnel for having an uptime of excellence (M. M. A. Silva et al., 2018). To (Sharma & Coyne, 2015), people are the main characters of DevOps culture.

5.2.3.7. Process

The DevOps process can be considered a business process because it aims to affect the entire lifecycle of an application as being a collection of activities or tasks that produce a specific result for customers (Hüttermann, 2012). When the DevOps approach is in place within an organization, all parties involved from the highest level of the business down to the operations should be able to have transparency and cooperate in the entire lifecycle of a change (M. M. A. Silva et al., 2018).

5.3.Step 3 (DevOps practices)

Having analyzed Table 5, and considering that there is a considerable gap between C6 and C7, the researcher has decided to identify all the practices for each capability from C1 and C6. Since that the information regarding these capabilities are spread in a lot of studies, each capability's practices will be synthetized by grouping it by Area.

After analyzing the descriptions of the areas from 5.2.3.1 to 5.2.3.7, the researcher has concluded that some areas identify themselves with other areas. Considering that it would be complex to detail all the practices of all these areas, and since there are areas that cover other areas, the researcher has decided to group some Areas. Thus, Technology will include Automation, Culture includes Sharing and Process includes Measurement.

This leave us with the four main Areas: Culture, Technology, People and Process. In order to study the practices from the Capabilities in a determined Areas, all the documents that were used in the SLR of the Capabilities and the Areas were analyzed.

The next tables (Table 8,

Table 9, Table 10,

Table 11Table 12 and

Table 13) presents all the practices found for DevOps capability, ordered by area.

Table 7 - DevOps Areas SLR

ID	Area	References	# of References
A1	*Culture*	(Bang et al., 2013; Bucena & Kirikova, 2017; Colomo-Palacios et al., 2018; de França et al., 2016; Debois, 2011; Diel et al., 2016; Erich, Amrit, & Daneva, 2014a; Gupta, Kapur, & Kumar, 2017; Hüttermann, 2012; Jabbari et al., 2016; Nielsen et al., 2017; Perera, Silva, & Perera, 2017; Rana & Staron, 2016; Sharma & Coyne, 2015; M. M. A. Silva et al., 2018; Smeds et al., 2015)	*16*
A2	*Measurement*	(Bang et al., 2013; Colomo-Palacios et al., 2018; de França et al., 2016; Debois, 2011; Erich et al., 2014a; Gupta et al., 2017; Hüttermann, 2012; Jabbari et al., 2016; Luz et al., 2018b; Nielsen et al., 2017; Perera, Silva, et al., 2017; Rana & Staron, 2016; M. M. A. Silva et al., 2018; Smeds et al., 2015)	*14*
A3	*Sharing*	(Bang et al., 2013; Colomo-Palacios et al., 2018; de França et al., 2016; Debois, 2011; Erich et al., 2014a; Gupta et al., 2017; Hüttermann, 2012; Jabbari et al., 2016; Luz et al., 2018b; Nielsen et al., 2017; Perera, Silva, et al., 2017; Rana & Staron, 2016; M. M. A. Silva et al., 2018; Smeds et al., 2015)	*14*
A4	*Automation*	(Bang et al., 2013; Colomo-Palacios et al., 2018; de França et al., 2016; Debois, 2011; Erich et al., 2014a; Gupta et al., 2017; Hüttermann, 2012; Jabbari et al., 2016; Luz et al., 2018b; Mohamed, 2015; Nielsen et al., 2017; Perera, Silva, et al., 2017; Rana & Staron, 2016; M. M. A. Silva et al., 2018; Smeds et al., 2015)	*14*
A5	*Technology*	(Abdelkebir et al., 2017; Bucena & Kirikova, 2017; Diel et al., 2016; Gazivoda, 2018; Hussain et al., 2017; Hüttermann, 2012; McCarthy et al., 2015; Sharma & Coyne, 2015; M. M. A. Silva et al., 2018; Sturm, Pollard, & Craig, 2017)	*10*
A6	*People*	(Abdelkebir et al., 2017; Bucena & Kirikova, 2017; Gazivoda, 2018; Hussain et al., 2017; Hüttermann, 2012; McCarthy et al., 2015; Sharma & Coyne, 2015; M. M. A. Silva et al., 2018; Sturm et al., 2017)	*9*
A7	*Process*	(Abdelkebir et al., 2017; Bucena & Kirikova, 2017; Gazivoda, 2018; Hussain et al., 2017; Hüttermann, 2012; McCarthy et al., 2015; Sharma & Coyne, 2015; M. M. A. Silva et al., 2018; Sturm et al., 2017)	*9*
A8	*Quality*	(Erich et al., 2014a; Luz et al., 2018b; Mohamed, 2015)	*3*
A9	*Collaboration*	(Luz et al., 2018b; Mohamed, 2015)	*2*
A10	*Diy Deployments*	(Debois, 2011)	*1*
A11	*Agility*	(Luz et al., 2018b)	*1*
A12	*Resilience*	(Luz et al., 2018b)	*1*
A13	*Transparency*	(Luz et al., 2018b)	*1*
A14	*Services*	(Erich et al., 2014a)	*1*
A15	*Structures*	(Erich et al., 2014a)	*1*
A16	*Standards*	(Erich et al., 2014a)	*1*
A17	*Governance*	(Mohamed, 2015)	*1*

Table 8 - CD Practices

	Continuous Deployment	
	Practice	**Author**
People	-	-
Process	Orchestrated deployments Track which version is deployed Manage the configurations of the environments of all the stages Manage the software components that get deployed Manage the middleware components and middleware configurations that need to be updated Manage the database components that need to be changed Manage the configuration changes to the environments to which these components are to be deployed	(Sharma & Coyne, 2015)
	Release working software any time, any place Label a repository's assets Produce a clean environment Label each build Create build feedback Reports Possess capability to roll back release	(Duvall, Matyas, & Glover, 2007)
	Multiple deployments to production Deploy a new release whenever one is needed	(Mohamed, 2016)
Technology	Development and production share a homogenous infrastructure Configuration management tools	(Ebert et al., 2016)
	Automated deployment of software to different environments	(Nielsen et al., 2017)
	Deployments should include the automated provisioning of all environments	(Debois, 2011)
	Automated deployment Continuous deployment	(Nielsen et al., 2017)
Culture	Early and frequent involvement of operations staff in the planning stages of major new releases	(Debois, 2011)

Table 9 - CI Practices

	Continuous Integration	
	Practice	**Author**
People	-	-
Process	Automation of tasks Provision of virtualized hardware resources via scripts (instead of doing manual configuration work) Developers should make use of continuous integration, that is branch-out and merge-back their work with the software mainline (the trunk) several times a day, in order to discover integration risks as early as possible	(Nielsen et al., 2017)
	Continuous integration cycles to include also software release. Continuous feedback loop	(de França et al., 2016)
	Enable rapid automated regression testing of code changes	(Marijan et al., 2018)
	Test in a clone of the production environment Make it easy for anyone to get the latest executable	(Sharma, 2017a)
Technology	Use of cloud services	(Nielsen et al., 2017)
	Tools interoperability for unifying force across diverse teams, skills, technology languages, and methodologies	
	Version Control An Automated Build	(Jez Humble & Farley, 2011)
	Use build servers Maintain a single-source repository Automate the build	(Sharma, 2017a)
Culture	Collaboration between teams	(Luz et al., 2018b)
	Development and QA teams perform unit and integration testing Operations participates in integration and load testing to assess operational readiness	(Sturm et al., 2017)
	Agreement of the Team	(Jez Humble & Farley, 2011)
	Make sure everyone can see what is happening	(Sharma, 2017a)

Table 10 - Continuous Monitoring Practices

	Continuous Monitoring	
	Practice	**Author**
People	Analysis skills	(Wiesche, 2018)
Process	Define some useful measurement metrics	(Nielsen et al., 2017)

	Ensure continuous feedback provided through the monitoring process and the users	
	Application monitoring System monitoring Application user behavior User sentiment Delivery pipeline metrics	(Sharma, 2017c)
	Systems are monitored after deployment	(L. Zhu et al., 2016)
	• Instrumenting your applications and your infrastructure so you can collect the data you need • Storing the data so it can easily be retrieved for analysis • Creating dashboards which aggregate the data and present it in a format suitable for operations and for the business • Setting up notifications so that people can find out about the events they care about	(Jez Humble & Farley, 2011)
Technology	Analytics can be used to integrate the system and infrastructure performance data with customer usage behavior	(Lwakatare et al., 2015)
	Not just gather this data but also run analytics on it	(Sharma, 2017c)
	Basic services such as dashboards	(Senapathi, Buchan, & Osman, 2018)
	Use a Realtime User Monitoring tool	(Erich, Amrit, & Daneva, 2014b)
	APIs or services The application should use to notify the operations team of its state	(Jez Humble & Farley, 2011)
Culture	Collaboration between developers and operations so that the systems are designed to expose relevant information	(Lwakatare et al., 2015)

Table 11 - Continuous Testing Practices

	Continuous Testing	
	Practice	**Author**
People	Understand test automation functions Automate tests Understand functionalities for test management	(Wiesche, 2018)
Process	Script-based testing early and throughout the software delivery process Shorten later testing cycles Ensure continuous feedback on quality	(Nielsen et al., 2017)
	Testing earlier and continuously across the life cycle	(Sharma & Coyne, 2015)
	High test coverage of high-risk areas	(Marijan et al., 2018)
	Integrate testing activities as closely as possible with coding	(Fitzgerald & Stol, 2014)
Technology	Virtualization to simulate the production environments	(M. M. A. Silva et al., 2018)
	Test case generation	(Vassallo et al., 2017)
Culture	Both IT Development and IT Operations should carry out quality assurance and be responsible for test automation	(Nielsen et al., 2017)
	Each developer should take personal responsibility for their code and write the test cases	(De Bayser et al., 2015)
	Testing on real users at scale	(Feitelson et al., 2013)
	Driving development with tests	(Vassallo et al., 2017)
	TDD is a development practice that starts with writing tests before you write any code BDD encourages working with the business stakeholder to describe the desired business functionality of the application ATDD builds on TDD and BDD, and it is involved in finding scenarios from the end user perspective	(Perera, Silva, et al., 2017)
	Testing/quality team is connected with Development team early in the development cycle to create the required test cases	(Mohamed, 2015)

Table 12 - Infrastructure as a Code Practices

	Infrastructure as code	
	Practice	**Author**
People	-	-
Process	Versioning environments	(Mohamed, 2016)
Technology	Entire infrastructure in a common language	(Luz et al., 2018b)
	Automate server Generic tools Application or middleware-centric tools Environment and deployment tools	(Sharma & Coyne, 2015)
Culture	Everyone knows how the execution environment of an application is provided and managed	(Luz et al., 2018b)

Table 13 - Feedback Loops Practices

	Feedback Loops between Dev and Ops	
	Practice	**Author**
People	Feedback ability, in both directions - so, to give feedback but also to accept it	(Wiesche, 2018)
Process	Shorten later testing cycles to ensure continuous feedback Ensure continuous feedback provided through the monitoring process and the users	(Nielsen et al., 2017)
	The frequency of integration is also important in that it should be regular enough to ensure quick feedback to developers	(Fitzgerald & Stol, 2014)
	Mechanisms to involve users in the development process and collect user feedback from deliveries as early as possible Techniques need to be nonintrusive so that users are not stressed with continuous feedback requests. Short feedback loops	(Rodríguez et al., 2018)
	Feedback loops strategy	(M. Science, 2016)
	The measurement results should be provided to not only the operation people, but also the development people	(Rong et al., 2016b)
	Any change, of whatever kind, needs to trigger the feedback process. The feedback must be delivered as soon as possible. The delivery team must receive feedback and then act on it.	(Jez Humble & Farley, 2011)
Technology	-	-
Culture	Share feedback freely without blame	(Perera, Bandara, et al., 2017)
	High focus on requirements Management through close relationship with the users to determine their needs and quickly react on their feedback	(Nielsen et al., 2017)
	Keeping a constant feedback about the current state of the system	(Rodríguez et al., 2018)

5.4.Step 4 (Maturity Levels)

The results of each conducted interview iteration are presented, followed by the associated emerging final MM for DevOps.

5.4.1. First Iteration

To perform the first round of interviews, 15 DevOps professionals were interviewed. The LinkedIn database was used to find the interviewees. Overall, 87 invites were made to DevOps experts and 33 were accepted. In this list of 33 contacts, only 15 responded to the interview.

In this research, it was considered the position of the possible participant, always willing to interview professionals with higher positions than DevOps developers. Interviewees information can be seen in Table 14.

Although some of the DevOps capabilities already exists, the term DevOps was born in 2011. The average age of the 15 interviewed is 39,4 years, while the average experience in DevOps is 5,6 years. Since DevOps was born 9 years ago, 5,6 years in average of experience means that the interviewed have been working in this area during more than half of its existence as a practice. Plus,13 out of the 15 interviewees work in the IT sector.

Table 14 - Information from the Interviewees

ID	Role	Age	DevOps Experience (Years)	Industry	First Iteration	Second Iteration
I1	*Head of DevOps Transformation*	*41*	*6*	*Software development*	*X*	*X*
I2	*Solution Architect*	*46*	*8*	*Software development*	*X*	*X*
I3	*Senior Manager*	*41*	*8*	*Software development*	*X*	*X*
I4	*Senior DevOps Engineer / Team Lead*	*26*	*3*	*Software development*	*X*	*X*
I5	*Head of Agile and DevOps Transformation*	*38*	*3*	*Software development*	*X*	*X*
I6	*DevOps Manager/Evangelist*	*42*	*3*	*Finance*	*X*	*X*
I7	*Lead DevOps specialist*	*39*	*3*	*Healthcare*	*X*	*X*
I8	*DevOps Architect*	*38*	*8*	*Software development*	*X*	*X*
I9	*DevOps Operations Lead*	*40*	*3*	*Software development*	*X*	*X*
I10	*DevOps Engineer*	*33*	*4*	*Software development*	*X*	*X*
I11	*Managing Director*	*48*	*8*	*Software development*	*X*	*X*
I12	*Senior Developer*	*38*	*6*	*Software development*	*X*	*X*
I13	*Lead DevOps specialist*	*45*	*8*	*Software development*	*X*	
I14	*Senior Manager*	*39*	*7*	*Software development*	*X*	
I15	*IT Development T. Leader - Applications*	*37*	*6*	*Software development*	*X*	*X*
	Average	*39,4*	*5,6*			

The same interviewer conducted all the 15 interviews ensuring that the same interview guides and protocol were used throughout the interviews. The first, second, third, fourth and last interviews were conducted in the participants' workplace, while the rest were carried out by Skype. The interview was semi-structured and aimed at exploring practitioners' experiences with DevOps practices. All the 15 interviews were conducted between March and June 2019.

The researcher has interviewed DevOps practitioners according to a preset script which included semi-structured open-ended questions. The interview guideline addressed topics such as the expert's background, expert's team and company information, DevOps practices and observations about it.

Grounded on maturity levels classification, and since all organization are at level 1 (ad-hoc) by default, the researcher has only asked the interviewees to associate the practices with levels 2, 3, 4 and 5. The distribution of the practices by levels is presented in Table 15.

Table 15 - Distribution of the number of practices per level from First Iteration

Level	Frequency
Level 2	*31*
Level 3	*50*
Level 4	*19*
Level 5	*9*

5.4.2. Second Iteration

All the 15 interviewees from the first iteration were asked to participate in a second round. From those, 13 accepted to participate. The objective of this phase was to breakdown the practices that had the same number of votes to more than one level of maturity and try to reach consensus on all practices. therefore, the participant had a chance to choose between the most voted levels of the first phase in each of the enlisted practices.

All the interviews were conducted by email. The interviews were semi-structured and aimed at exploring practitioners' experiences with DevOps practices. All the 13 interviews were conducted between June and August 2019.

DevOps practitioners were interviewed according to a preset script which included semi-structured open-ended questions. The interview guideline addressed topics such as DevOps practices and observations about it. Since no relevant conclusions could be drawn from the first iteration, in this second phase the authors changed the possible answers for the DevOps practices maturity levels to the most voted levels from the first phase. This was held since there were many maturity levels for each practice.

Grounded on maturity levels classification, and since all organization are at level 1 (ad-hoc) by default, the researcher only asked the interviewees to associate the practices with the most voted levels for each practice from the first phase. The distribution of the practices by levels and the difference from the first iteration are presented in Table 16.

Table 16 - Distribution of the number of practices per level from Second Iteration

Level	Frequency	Difference
Level 2	*10*	*-21*
Level 3	*54*	*+4*
Level 4	*27*	*+8*
Level 5	*18*	*+9*

Analyzing Table 16, one of the most relevant difference between the two phases is the migration of some level two responses to the other levels. There is a clear increase of level 5 votes. On the other hand, level 3 continues to be the most voted level.

Only about one third of the previous level two votes remained. Although none of the participants said anything about this, it seems that, since each participant had the chance to choose from the most voted level from the first iteration, they considered a higher level since that it was a possibility. Also, since that two from the first iteration interview did not answer this issue, it may have had an influence on this result.

The most voted levels are concentrated in two levels: three and four. The participants only considered 18 practices to belong to a much higher maturity level (level 18). Since level three is one of the most basic level, it had a much higher number of practices.

5.4.3. Maturity Model

Heaving completed all interview's stages, the researcher presents the final MM in this section. Although it is a single model, for its better comprehension, it was divided into 6 parts, one for each capability. Even though the interviewees had the chance to add or remove practices from the initial list, none of them did. This means that the initial list of DevOps practices remained unchanged through all these interview phases. Although every participant had the chance to remove a practice and/or add an observation, there were only few cases where it happened. However, since it was not coherent nor consistent among the participants, those removed practices and observations were not taken in consideration.

Each MM table is divided by areas (People, Process, Technology and Culture) in which are presented the respective practices. The next tables (Table 17, Table 18, Table 19, Table 20 and Table 21) present de MM for DevOps. According these tables that, together, integrate the MM for DevOps, an analysis has been made.

Observing Table 17, it is possible to devise that there is only one practice from level 2. Level 3 is the level with more practices and level 4 and level 5 almost have the same number of practices. Looking to the practices per area, since the author was not able to find any practice associated with this area and the interviewees did not add any, People does not have any practice. on the other hand, Process seems to be the area with more practices, since it has at least one at each level.

Table 18 has in common with the previous table the fact that People does not have any associated practice. On the other hand, level 2 is more populated than it was in the previous table. Level 3 is the level with more practices, while Process continues to be the area of DevOps with more practices. Technology has at least a practice per level.

In the Continuous Monitoring (Table 19) it is possible to see the first practice for the People's area and is the only practice for the level 2 on this table. Process and Technology have practices from the level 3 to level 5.

Table 20 People's area contains more practices than the tables before. There are three People practices and they are all in level 3. Culture is the most completed area in this table, since it has practices in every level. Level 5 only has one practice.

Table 21 is the one with less practices. The author could not identify more practices from the literature and the interviewees did not add any. Level 3 is the most populated level and there is only on practice that does not belong to this level. Technology is the Area with most practices. On the other hand, there is no practice in People's area.

Last but not least,

Table 22 presents all the practices from Feedback Loops capability. There was not found any practice in level 2. Level 3 only have practices for the Process area, while level 4 contains practices for People, Process and Culture. Culture seems to be an area where all its practices are from a greater maturity, since three out of four practices presented in this area belong to level 5. The level with more practices is level 4.

After analyzing all the tables that contained the MM for DevOps, a last analysis must be conducted. The preliminary list for the MM was conducted by the author, through a literature review. Although the fact that all the interviewees had the chance to add or remove any practices they want, none of them did. This result in some capabilities with less practices than others, and some areas with just few practices. If any of them had less than four practices, it means that there will be levels with no practices. This is clear in Table 21.

People is the area with less practices from the four. On the other hand, Process, followed by Technology are the areas with more practices. Level 3 is the level with most practices while level 2 is the one with less practices. This may be due to the lack of literature about this theme.

Table 17 - CD MM

		Level 2	Level 3	Level 4	Level 5
Continuous Deployment	People				
	Process	CD9 Label a repository's assets	CD2 Track which version is deployed CD3 Manage the configurations of the environments of all the stages CD4 Manage the software components that get deployed CD5 Manage the middleware components and middleware configurations that need to be updated CD6 Manage the database components that need to be changed CD10 Produce a clean environment CD11 Label each build CD12 Create build feedback Reports CD14 Deploy a new release whenever one is needed CD17 Automated deployment CD18 Continuous deployment	CD1 Orchestrated deployments CD16 Deployments should include the automated provisioning of all environments	CD1 Orchestrated deployments CD7 Manage the configuration changes to the environments to which these components are to be deployed CD8 Release working software any time, any place CD15 Multiple deployments to production
	Technology	-	CD19 Development and production share a homogenous infrastructure CD20 Configuration management tools	CD21 Automated deployment of software to different environments	-
	Culture	-	CD22 Team must provide overall visibility into your application release activities and timing to all major stakeholders CD25 Unite the two teams that worked independently to work at tighter integration CD26 Both development and operations personnel should share the same knowledge management resources CD27 Testers and operations personnel would be able to self- service deployments of the required version of the system to their environments on demand CD28 Early and frequent involvement of operations staff in the planning stages of major new releases	CD24 Team must be able to speed lead times and make more frequent application deployments at the pace demanded by the business	CD23 Teams must be able to provide self-service, on-demand provisioning and management of cloud environments and infrastructure resources

Table 18 - CI MM

		Level 2	Level 3	Level 4	Level 5
Continuous Integration	People	-	-	-	-
	Process	CI8 Make it easy for anyone to get the latest executable	CI1 Automation of tasks CI2 Provision of virtualized hardware resources via scripts (instead of doing manual configuration work) CI3 Developers should make use of continuous integration, that is branch-out and merge- back their work with the software mainline (the trunk) several times a day, in order to discover integration risks as early as possible CI5 Continuous integration cycles to include also software release CI6 Enable rapid automated regression testing of code changes	CI4 Continuous feedback loop CI7 Test in a clone of the production environment	-
	Technology	CI11 Version Control CI15 Automate the build	CI12 An Automated Build CI13 Use build servers	CI9 Use of cloud services	CI10 Tools interoperability for unifying force across diverse teams, skills, technology languages, and methodologies CI14 Maintain a single-source repository
	Culture	CI16 Collaboration between teams CI19 Agreement of the Team	CI17 Development and QA teams perform unit and integration testing	CI18 Operations participates in integration and load testing to assess operational readiness CI20 Make sure everyone can see what is happening	-

Table 19 - Continuous Monitoring MM

		Level 2	Level 3	Level 4	Level 5
Continuous Monitoring	People	CM1 Analysis skills	-	-	-
	Process		CM4 Application monitoring CM5 System monitoring CM8 Delivery pipeline metrics CM11 Storing the data so it can easily be retrieved for analysis CM13 Setting up notifications so that people can find out about the events they care about	CM2 Define some useful measurement metrics CM6 Application user behavior CM7 User sentiment CM9 Systems are monitored after deployment CM10 Instrumenting your applications and your infrastructure so you can collect the data you need CM12 Creating dashboards which aggregate the data and present it in a format suitable for operations and for the business	CM3 Ensure continuous feedback provided through the monitoring process and the users
	Technology		CM16 Basic services such as dashboards CM17 Use a Realtime User Monitoring tool CM18 APIs or services	CM19 The application should use to notify the operations team of its state	CM14 Analytics can be used to integrate the system and infrastructure performance data with customer usage behavior CM15 Not just gather this data but also run analytics on it
	Culture		CM20 Collaboration between developers and operations so that the systems are designed to expose relevant information		

Table 20 - Continuous Testing MM

		Level 2	Level 3	Level 4	Level 5
Continuous Monitoring	People	-	CT1 Understand test automation functions CT2 Automate tests CT3 Understand functionalities for test management	-	-
	Process	-	CT4 Script-based testing early and throughout the software delivery process CT6 Ensure continuous feedback on quality	CT5 Shorten later testing cycles CT7 Testing earlier and continuously across the life cycle CT8 High test coverage of high-risk areas CT9 integrate testing activities as closely as possible with coding	-
	Technology	-	CT10 Virtualization to simulate the production environments CT11 test case generation	-	-
	Culture	CT15 driving development with tests CT16 TDD is a development practice that starts with writing tests before you write any code CT19 Testing/quality team is connected with Development team early in the development cycle to create the required test cases	CT13 Each developer should take personal responsibility for their code and write the test cases CT17 BDD encourages working with the business stakeholder to describe the desired business functionality of the application CT18 ATDD builds on TDD and BDD, and it is involved in finding scenarios from the end user perspective	CT12 Both IT Development and IT Operations should carry out quality assurance and be responsible for test automation	CT14 Testing on real users at scale

Table 21 - Infrastructure as Code MM

		Level 2	Level 3	Level 4	Level 5
Continuous Monitoring	People	-	-	-	-
	Process	-	IAC1 Versioning environments	-	-
	Technology	-	IAC2 Entire infrastructure in a common language IAC3 Automate server IAC4 Generic tools IAC5 Application or middleware-centric tools IAC6 Environment and deployment tools	-	-
	Culture	-	-	-	IAC7 Everyone knows how the execution environment of an application is provided and managed

Table 22 - Feedback Loops MM

		Level 2	Level 3	Level 4	Level 5
Continuous Monitoring	People	-	-	FL1 Feedback ability, in both directions—so, to give feedback but also to accept it	-
	Process	-	FL2 Shorten later testing cycles to ensure continuous feedback FL4 The frequency of integration is also important in that it should be regular enough to ensure quick feedback to developers FL7 Short feedback loops FL11 The delivery team must receive feedback and then act on it.	FL3 Ensure continuous feedback provided through the monitoring process and the users FL5 Mechanisms to involve users in the development process and collect user feedback from deliveries as early as possible FL8 Feedback loops strategy the measurement results should be provided to not only the operation people, but also the development people FL10 The feedback must be delivered as soon as possible.	FL6 Techniques need to be nonintrusive so that users are not stressed with continuous feedback requests. FL9 Any change, of whatever kind, needs to trigger the feedback process.
	Technology	-	-	-	-
	Culture	-	-	FL13 High focus on requirements	FL12 Share feedback freely without blame FL14 Management through close relationship with the users to determine their needs and quickly react on their feedback FL15 Keeping a constant feedback about the current state of the system

Chapter 6 – Demonstration

In order to demonstrate the artifact, two teams fully compliant with DevOps were assessed. Then, an interview was held with DevOps teams where the proposed MM was tested. The objective is to demonstrate that the MM fulfils the purpose it was designed to applying it in a professional environment. Since not all capabilities or areas have practices, only the capabilities/areas with at least one practice have been considered to assess teams maturity. According with CMMI, which has been previously presented, a level can only be reached if all the practices from that level are executed.

6.1 First demonstration

The first team assessed operates in the services sector, in the field of Cloud and DevOps consulting. The person responsible to conduct this demonstration is the DevOps Operations Lead with three years of experience in DevOps. The next figure (Figure 11) shows the maturity of the DevOps in this team.

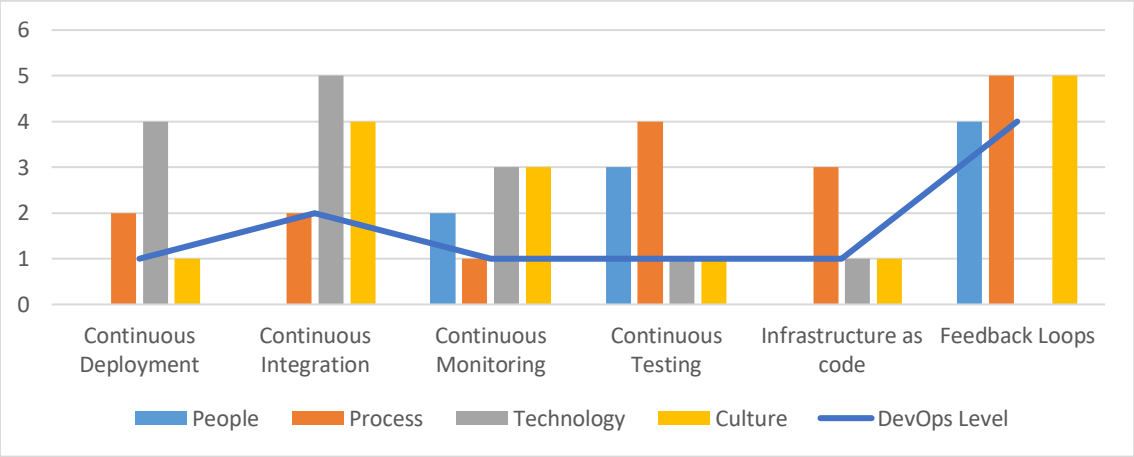

Figure 11 - First demonstration maturity

Figure 11 shows the maturity of the first team. As it evidences, the most matured capability is the Feedback Loops, followed by CI.

At level 4, Feedback Loops has a maturity level almost all areas at level 5, if it was not by the People's area. This means that the team has all the practices implemented for Culture and Processes, and a big part of the People's practices. Looking to the CI, Technology is at its maximum, level 5. Culture is the next area with more maturity and Process is at the end.

Looking to the other capabilities, they all are at level 2. Continuous Monitoring has 3 areas at level 3 and seems to be the next most maturated capability.

In a more general view, the most maturated capability is Feedback Loops. The most maturated area is Process.

6.2 Second demonstration

The second team is from the SD industry. The person responsible to conduct this demonstration is the Senior Manager with eight years of experience in DevOps. The next figure (Figure 12) shows the maturity of the DevOps in this team.

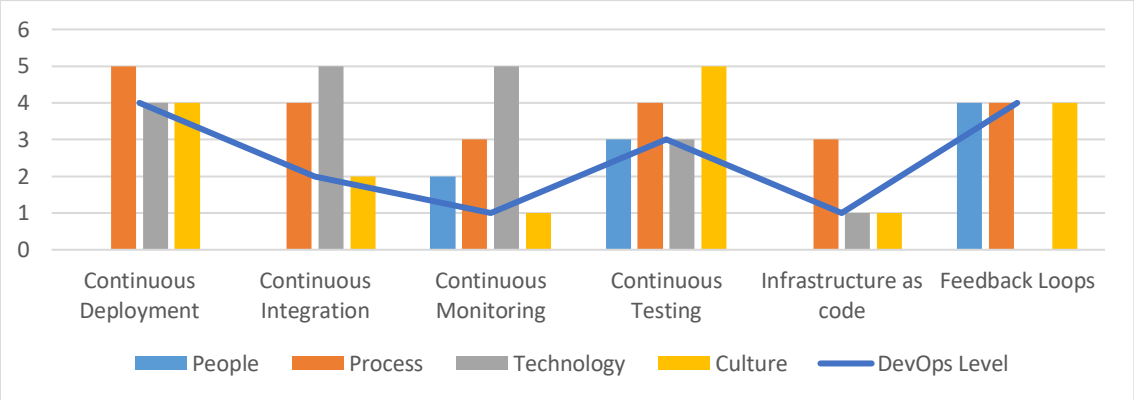

Figure 12 - Second demonstration maturity

Looking at this figure, it is perceptible that this team has, in general, a much higher maturity than the previous one. Two capabilities at level 4 and one in level 3. CD, Feedback Loops are the most matured capabilities while Infrastructure as a Code is the less matured one.

Looking to the CD graphic, one of the areas reached level 5, while the others are at level 4. Feedback loops has all its areas with similar maturity levels. Continuous Testing has one area in level 5, one in level 4 and the others in level 3.

CI, although it has 1 area in level 5 and another one in level 4, it is only in the maturity level 2, due to its lack of culture maturity. Continuous Monitoring has the same problem: although it has 1 area in level 5, one in level 4 and another in level 3, its maturity is only 2. The most immature capability is Infrastructure as a Code. On the three areas evaluated, only one is above level 2.

Chapter 7 – Evaluation and Communication

In accordance with the DSRM evaluation step, here is presented our plan to evaluate the proposal artefact in order to prove the relevance and applicability of the artefacts produced in the resolution of the research problem described in section 3.

Following the Pries-Heje, Baskerville, & Venable (2008) approach, in which the authors present the importance of an ex ante perspective, with the evaluation occurring both prior to the construction of an artefact IS, and an ex post evaluation, that is, evaluations that take place after the artefact has been built. Plus, Venable identifies two main forms for the DSRM evaluation (J. R. Venable, 2006):

- **Artificial Evaluation** is evaluating a solution technology in a contrived, non-real way.
- **Naturalistic evaluation** enables a researcher to explore how well or poorly a solution technology works in its real environment – the organization.

Furthermore, an additional dichotomy is incorporated into the Pries-Hege's framework, which is comprised of the design product and design process. Using the definition of Dubin for each aspect of design theory (Dubin, 1976):

- **Design product** is "a plan of something to be done or produced"
- **Design process** is "to so plan and proportion the parts of a machine or structure that all requirements will be satisfied"

By distinguishing all these concepts, it is possible to map the objectives of evaluation and what is more accurately adapted to the artefact constructed in order to prove the utility, effectiveness and other criteria, as shown in Figure 13.

This framework for the DSRM evaluation is supposed to facilitate the answer to the following questions – "What" is evaluated, "When" to evaluate, and "How" to evaluate.

Figure 13, helps us to answer these questions by providing a high-level perspective, also considering that "P summarizes the essential characteristics of the evaluation Process, while C indicates the evaluation Criteria (Pries-Heje et al., 2008).

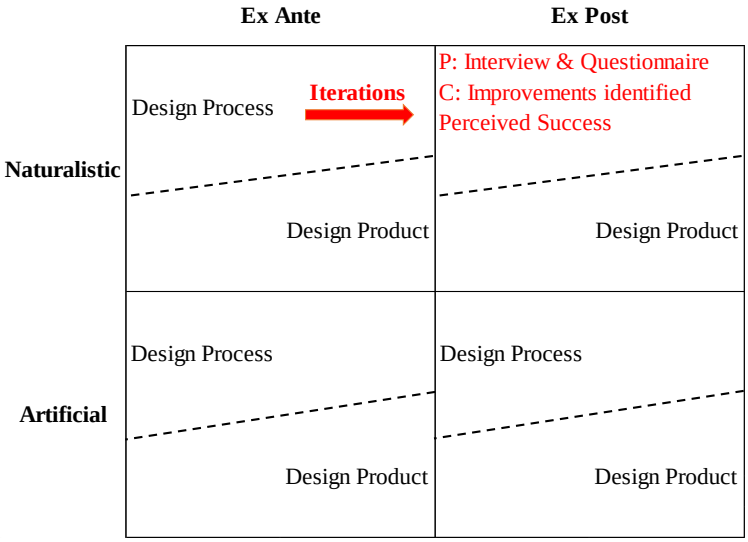

Figure 13 - Strategic DSRM evaluation framework. Adapted from (Pries-Heje et al., 2008)

However, further details are needed to answer these questions and several decisions need to be made. This non-compliance is fulfilled with the proposed framework by J. Venable, Pries-Heje, & Baskerville (2012) that is intended to be a complement to the strategic DSRM evaluation framework mentioned above, providing for example a guide on how to select evaluation methods.

The DSRM Evaluation Method Selection Framework suggests possible evaluation methods. For the current study, Survey was selected, in a form of interviews and questionnaires.

At this point, by analyzing Figure 13 and using the selected methods of Figure 14, the answers to the previously mentioned questions are as follows:

- What is intended to evaluate? In this case it is the developed DevOps MM.
- How will it be evaluated? The researcher will perform a survey.
- When will be evaluated? It will be evaluated following an iteration approach, basically as an ex-post evaluation

Concerning research communication, a part of this research is presented by one paper and the whole research is represented by this document.

The researcher will now show the evaluation that was given by the demonstration inquires, where the constructed MM was applied by DevOps practitioners in its teams. The researcher asked the participant to evaluate the proposed MM. the inquired person had the chance to say anything he wanted about this MM, if it was useful, complete or applicable in real life cases.

DSR Evaluation Method Selection Framework	Ex Ante	Ex Post
Naturalistic	Action Research Focus Group	Action Research Case Study Focus Group Participant Observation Ethnography Survey (qualitative or quantitative) ←
Artificial	Mathematical or Logical Proof Criteria-Based Evaluation Lab Experiment Computer Simulation	Mathematical or Logical Proof Lab Experiment Role Playing Simulation Computer Simulation Field Experiment

Figure 14 - DSR Evaluation Method Selection Framework. Adapted from (J. Venable, Pries-Heje, & Baskerville, 2012)

This first evaluation corresponds to the First demonstration case, where the participant of 40 years old and 3 years of experience on the DevOps field applied the MM in his team. The second evaluation is from the SD industry, where the participant is responsible to conduct this demonstration is the Senior Manager with eight years of experience in DevOps. The following was stated (**Error! Reference source not found.**):

The participants evaluated the MM positively as it can be seen in evidenced by their feedback. On the first case, the participant said that it is a valuable work and it can be a good help for the DevOps implementation. The participant also said that as a service provider, some practices can be hard to get through because they are a true challenge to implement.

The second participant in the evaluation stated that this MM is a useful tool to know the maturity of DevOps in a team. The fact that the MM was build based on the literature and improved with DevOps practitioners, gives this research more credibility. Although the participant considers this MM complete, for him, it could get better if all the Areas had at least one practice, so it can measure the maturity of all the DevOps.

Taking these two evaluations in consideration, the feedback received is positive. Both participants thought this is a useful tool to measure the DevOps adoption. By the feedback, it is possible to perceive that this MM is applicable in real cases. The suggestion of improving the model to have at least one practice in each area is shared by the researcher. However, it was not possible to find in the literature studies that deeply explore DevOps and the people interviewed for the construction of this MM did not add any practice.

Table 23 - Evaluations of the MM applicability

ID	*Evaluation*
E1	"You produced such valuable work. This list can act as a service menu for a DevOps process and culture implementation and at the same time this will help the person in charge of the DevOps transformation keep the focus on what should be delivered to the stakeholders. As a service provider, I cannot deny the difficulty to address some targets of your work with my clients. For example, when you are working to transform an ITIL organization to an Agile/DevOps organization, people tend to refrain the changes and points as the " Share the feedback freely without blame" are a true challenge to be implemented. For me, decide which parts of your practices should or not be implemented is a matter to balance the client needs, the size of the client organization and keep the process as simple as possible."
E2	"It is hard to find DevOps practices in the existent literature. It is even harder to understand what is important and what is the correct order to implement, so the team has solids basis. This work provides an interesting set of DevOps practices, divided by the most important capabilities. It is even better because I can have a vision by area. Applying this MM to our team gave me insight into what should be implemented and in what order. Knowing that this was made with interviews to DevOps practitioners give me more confidence in using this model as basis to future team improvements decisions, as I can rely on this research. This is a useful tool if you want to know the maturity of your team in DevOps. Although I believe that it is a complete tool, I would consider it more complete if it has more practices. At least, if every capability and every area had at least one practice."

Chapter 8 – Conclusions

In this research two SLR were conducted to respond to the call by researchers and practitioners for a deeper theoretical and practical understanding of DevOps capabilities and areas that could work as determinant factors and contribute to the implementation of DevOps. Then, a total of 28 interviews were performed with DevOps practitioners. With their experience, the interviewees helped to assign a specific maturity level for each DevOps practice. At the end of the previous steps, the proposed MM for DevOps was then completed. Grounded on the previous sections one may argue that all the proposed Research Objectives were achieved:

- Concerning RO1.1, the main DevOps capabilities have been also identified and detailed. The elicited capabilities include CI, CD, continuous testing, feedback loops between Dev and Ops and infrastructure as code.
- Regarding RO1.2, the main DevOps areas were elicited and described, and they specifically include culture, measurement, sharing, automation, technology, people and process.
- After these sub-objectives are met, a MM for DevOps was built. It was sustained on the previous main areas and main capabilities. It was developed a new DevOps MM based on CMMI MM to enable assessing any organization working model/state against DevOps model

Regarding this, the main objectives that this research proposed were hit. Despite this, it was possible to conclude the following set of insights:

- Both DevOps practitioners and scientific studies continue to increase since 2015. This study also identified some relationships between the DevOps areas and capabilities based on the analysis of Figure 7. The documents that focus on the DevOps culture are most likely to relate it to all of the main capabilities found. On the other hand, it is more difficult to find a document that relates Technology, People and Process with the main capabilities.
- The capabilities of CI and CD are the more investigated in the literature. The areas that most relate with them are Culture, Sharing and Automation. These three areas are the most referred DevOps areas in the literature. Processes seems to be the area that less influences the capabilities, while Infrastructure as Code is the capability which the fewest studies tend to relate with DevOps.

- This research has brought contributions to the academic and scientific community by exploring a field that had not yet been explored and proposing a novel artifact. It has also improved the knowledge base and endeavored to lay down new bases for further research.
- This research is a new systematized contribution to knowledge, through the identification of patterns that have been recognized in the literature - and that, as such, corresponds to a new level of knowledge in the approach to the topic. This research also provides some contributions for professionals and practitioners. In the absence of studies exploring the DevOps main capabilities and DevOps areas, and even the relationship between them, this research brings new insights on how and why practitioners should adopt DevOps practices and which areas they have to change or, at least, keep in mind as being relevant for an effective adoption of DevOps.
- Based on these findings, and using the summarized information provided in this work as a starting point, the authors deepened the identified DevOps areas and capabilities to be an a priori and open model, which was the target of this research project - which aimed to test and refine this systematized view (in the form of a MM), having not only implications for existing scientific knowledge but also being useful for organizational practices of DevOps
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8.1 Limitations

Regarding limitations, it was not possible to gather enough information and present a robust conclusion regarding specific topics, such as Outcomes, since DevOps is a recent subject. The current research cannot fully avoid biases since it has excluded literature sources written in other languages or unavailable in electronic databases. Since DevOps is recent, there are not a lot of experts in this area. This limited the interviews on each phase.

8.2 Future Work

In the future, research should be carried out into the most referenced capabilities, CI and CD and the most referenced areas, Culture, Sharing and Automation, as they seem to be essential in the DevOps movement. Also, it would be interesting to deeply explore the

relationship between CI and Culture, Sharing and Automation, as these areas seem to relate the most with the main capability found among this literature review.

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