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DevOps: An Innovation Attributes Perspective

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ABSTRACT

DevOps represents a significant departure from traditional IT operations and development practices. Employees may not view the associated changes positively. Little research has investigated the impact of tech workers' perspectives on DevOps adoption. This study evaluates a conceptual model in which employee perceptions of DevOps are antecedents of adoption intention.

KEYWORDS: DevOps, software development, adoption intention, innovation diffusion,

INTRODUCTION

Stasis is the enemy of innovation. Organizations which calcify their structure tend to have difficulty competing with smaller upstarts because they lack their flexibility and interconnectedness among teams (Ensor, 1988). Mature organizations tend to lose themselves in bureaucracy. They become static and no longer push the envelope. This is especially dangerous for organizations which develop and implement their own software, because software systems are a differentiator in crowded business sectors (Leistner, 2010). Sometimes innovativeness will re-emerge organically, especially if the right people are brought onboard and inter-departmental communication is fostered. Sometimes it must be encouraged. Managerial philosophies such as DevOps tear down departmental silos and leave a flattened, open structure.

Specially, DevOps restructures development and IT operations departments to create multidisciplinary teams which share responsibility and authority for delivering software-based solutions faster and cheaper (Dyck, Penners, & Lichter, 2012). It encourages innovativeness through practices such as agile planning, continuous integration, continuous delivery, and application monitoring. DevOps teams are designed to work quickly because traditional bottlenecks are removed and authority to fix and improve is granted (Hutterman, 2012). Further, because individuals are pushed to become team players, their work performance is evaluated according to macro-level metrics in addition to individual statistics. If software is broken or a service is offline, any member of a DevOps team could and should fix it.

For managers, DevOps seems like a solution to many problems. It flattens IT departments, increases responsiveness, and improves system uptime. However it calls for a number of non-trivial changes to frontline contributors – those who are affected by the change (Violino, 2016). Organizational structure, job scope, responsibility, workload, and performance measures change at the same time (Ashford, 1988). This can make DevOps much less appealing. Organizations considering adoption of DevOps must consider the attitudes of those most affected by the change. If these individuals are not sold on the benefits of DevOps then the adoption will likely be less than successful (Roche, 2013). Accordingly, the purpose of this research is to establish a model for predicting IT and software engineers' attitudes toward DevOps.

This research uses innovation diffusion theory to understand the relationship between workers' perceptions of DevOps and their willingness to consider adoption. Specifically, it proposes a behavioral model in which potential DevOps implementation is an antecedent to five attributional constructs: relative advantage, compatibility, ease of use, trialability, and results demonstrability (Moore & Benbasat, 1991). In turn, the attributional constructs are antecedents of adoption intention. The present study focuses on the attributes of the innovation because diffusion theory holds that in the early stages of the diffusion of an innovation potential adopters have less opportunity for observation and shared experience (Rogers, 1995; Van de Ven & Poole, 1995). In such cases, the crux of the decision is based on personal observation rather than factors such as social exchange (Berger & Bradac, 1982).

The remainder of this paper is organized as follows: The following section reviews background literature. It introduces the reader to DevOps and innovation diffusion theory. The following section is theoretical development. It conjectures a series of hypotheses and introduces the research model. The next section contains the methods. It describes the sample, measurements, and procedures used the test the hypotheses. The results of the tests are described in the following section. Finally, the last section provides concluding comments.

LITERATURE REVIEW

This section provides context for the proposed research model. First, a working definition of DevOps and its core dimensions is provided. Next, innovation diffusion theory is introduced.

Introduction to DevOps

DevOps is a combination of people, processes, and software arranged to enable continuous delivery of high quality value to end users. The word "DevOps" is meant to represent a combination of development and operations silos into a single function. This concept hinges on multidisciplinary teams with members from the software development and IT operations disciplines (Hutterman, 2012). These teams use a mix of tools to support seamless software upgrades and release management. DevOps is reliant on configuration management solutions such as Chef or Puppet to automate implementation and provide standardized builds. These solutions render container objects or virtual machines to contain bespoke software. DevOps also makes use of version management solutions such as Git to control the release pipeline. Within the software methodology space DevOps incorporates practices such as agile software development, continuous integration, high-availability, and continuous delivery.

DevOps is typically defined in terms of several key practices (Lwakatare, Kuvaja, & Oivo, 2016). These practices are usually adapted to specific business requirements but contain the following common attributes: (1) Agile software development. These are techniques for organizing work into a series of short sprints, managing team capacity, and helping teams quickly adapt to changing business requirements. (2) Version control. Teams must be able to control builds, implement patches, and monitor software commits. Tools such as GitHub help support build management and automate software release. (3) Continuous integration. This concept focuses on ongoing merging and testing of code. A key goal is to minimize defects or broken builds. (4) Continuous delivery. High levels of available are achieved by simplifying tests and maximizing similarities between test and production environments. This is often achieved using containers or virtual machines. (5) Monitoring. Constant monitoring of applications in production environments is a responsibility of operations experts and developers. (6) Infrastructure-as-code is a practice which enables the programmatic development, administration, and teardown of networks, virtual machines, and containers to support service delivery. (7) Microservice architectures. Software is shelled within the smallest possible unit to maximize efficiency and scalability.

Although DevOps brings a number of advantages to the organization, employees may not interpret every change as a positive. For instance, DevOps calls for a number of profound changes to work structure and roles (Dyck et al., 2012). Software developers are expected to help support production systems and respond to incidents involving the software they created while operations workers are expected to participate in early phases of the project management lifecycle. Further, workers are incentivized and rewarded by unfamiliar metrics. In addition, delineation of responsibility is blurred. These changes are expected to have a negative impact on perceptions and attitudes within the organization (Leistner, 2010), with highly-regulated industries experiencing especially difficult implementations (Yasar, 2017). Therefore, it is paramount that organizations consider employee perceptions prior to committing to DevOps implementation. Our research extends the current knowledge of DevOps adoption by examining employee perceptions through the theoretical lens of innovation diffusion.

Attributes of Innovations

Innovation diffusion theory seeks to explain how and why new concepts and ideas spread throughout social systems (Rogers, 1995). Some innovations spread quicker than others and some innovations never reach the critical mass required to sustain widespread adoption. Adoption decisions depend on factors such as attributes of the innovations, communication channels, social systems, and time. The perceived attributes of an innovation are an important explanation for individual adoption decisions within an organization. From 49 to 87 percent of the variance in adoption is explained by 5 constructs: relative advantage, compatibility, ease of use, trialability, and results demonstrability (Rogers, 1995). Each is somewhat empirically interrelated to the others but they are conceptually unique (Moore & Benbasat, 1991). The importance of understanding individuals' perceptions of innovation attributes cannot be understated. The opinions of the IT operations and software engineers matter when it comes to DevOps adoption because they will be implementing the associated practices (Roche, 2013).

Of the five attributes of innovations, relative advantage usually has the highest explanatory power. It is defined as the degree to which an innovation is perceived as being better than the idea it supersedes. The degree of relative advantage is generally expressed in terms of economic benefit, social standing, or other type of benefit. Compatibility, the second attribute, is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. An idea that is more compatible brings less uncertainty and risk to the potential adopter. This compatibility helps the individual give meaning to the idea so it is regarded as familiar. The third attribute is ease of use. This is the degree to which an innovation is perceived as relatively difficult to understand and use. Some concepts are less clear in their meaning to potential adopters than others. The ease of use of an innovation, as perceived by potential adopters, is inversely related to the rate of adoption. The next attribute is trialability. This is the degree to which an innovation may be experimented with on a limited basis. Innovations that can be tried without requiring full adoption are more palatable to potential adopters. The final construct is results demonstrability. This is the degree to which the results of an innovation are visible to others. Innovations which are more amenable to observation and are easier to interpret.

THEORETICAL DEVELOPMENT

Having previously laid the conceptual groundwork, this section provides a series of hypotheses regarding the relationship between DevOps, its key attributes, and adoption intention among organizational members. The first group of hypotheses (H1 – H5) represents the formation of perceptions following initial introduction to DevOps. The second group of hypotheses (H6 – H10) represent the impact of perceptions on adoption intention.

The first hypothesis concerns the relationship between proposed DevOps implementation and relative advantage. Affected employees, after learning about the changes associated with an organizational DevOps implementation, are expected to develop a significant, negative assessment of its relative advantage (Karahanna, Ahuja, Srite, & Galvin, 2002). Although the organization may benefit from the changes, the employee is likely to focus on the downsides specific to his or her job. Longer hours, more responsibility, changes in performance rating, and other factors may not be taken positively by employees. Therefore, the first hypothesis is:

H1: Potential adopters will form significant, negative perceptions of DevOps' relative advantage.

The next hypothesis concerns the relationship between DevOps and compatibility. It holds that workers will develop negative perceptions of DevOps' compatibility with their work. This result is expected because for many workplaces, DevOps represents a significant step away from standard business practices, requires changes in organizational structure, and calls for new lines of authority and responsibility. Previous studies hold that the greater the perceived differences, the greater the level of incompatibility (Agarwal & Prasad, 1998). Therefore:

H2: Potential adopters will form significant, negative perceptions of DevOps' compatibility.

The following hypothesis purports a negative relationship between organizational DevOps implementation and potential adopters' perceptions of ease of use. This link is theorized on the assumption that potential adopter will perceive a gulf between their current work functions and DevOps functions, thereby increasing the difficulty of transitioning. Larger perceived differences will result in more negative views of ease of use (Davis, 1989). According, the following hypothesis is offered:

H3: Potential adopters will form significant, negative perceptions of DevOps' ease of use.

Trialability is the degree to which an innovation may be tested or evaluated on a limited basis. The ability to test without a deep commitment is interpreted as an advantage because potential adopters can back out if they aren't prepared to adopt the innovation. It is expected that on consideration software developers and operations engineers will determine that their organization cannot trial the DevOps space without significant commitment. In order to implement DevOps, the organization must abandon its current development and operations methodologies. This is effectively a zero-sum choice. The concept of steep switching costs has been observed in the past for other related managerial innovations (Ettlie & O'Keefe, 1982), and employees tend to fear such changes. Therefore, it is expected that the link between potential workplace DevOps implementation and trialability will be significant and negative. And so:

H4: Potential adopters will form significant, negative perceptions of DevOps' trialability.

The next concept is results demonstrability. This is the extent to which the results of an innovation are visible to others. The ability to observe the efficacy of an innovation is of value to adopters. Before they consider adopting an innovation for themselves, potential adopters will attempt assess the outcome of using the innovation (Benham & Raymond, 1996). This process is part of the value assessment. Innovations which offer a clear improvement are more likely to be adopted than those which are less transparent. Because DevOps is purely conceptual and difficult to assess, it is expected that potential adopters will find that the results of potential adoption are difficult to envision. Therefore:

H5: Potential adopters will form significant, negative perceptions of DevOps' results demonstrability.

Having established that members of software and operations teams will form significant, negative perceptions of DevOps, the following hypotheses propose significant relationships between DevOps perceptions and intention to adopt DevOps. The first hypothesis holds that relative advantage will be significantly linked to adoption intention. Relative advantage is perception based on potential adopters' assessment of the benefits and costs of adopting relative to other concepts. Greater relative advantage has been shown in previous studies to result in stronger adoption intentions (Yi, Jackson, & Park, Probst, J.). For the present study, those who perceive significant relative advantages in DevOps will form stronger adoption intentions. Therefore:

H6: Relative advantage will have a significant, positive influence on adoption intention.

Compatibility is the perception of how closely an innovation aligns with existing processes, concepts, and beliefs. It held to significantly impact adoption intention. Innovations which are easily integrated into extent systems are easier to adopt, less must be modified in order to facilitate the change. The importance of fit cannot be understated. Even innovations which offer significant advantage may be bypassed if they do not fit the landscape in which they would be implemented (Agarwal & Prasad, 1997). Therefore, individuals who judge that DevOps is compatible with their work environment are expected to form stronger adoption intentions than those who do not. Accordingly:

H7: Compatibility will have a significant, positive influence on adoption intention.

For this research, ease of use concerns the efficacy of implementing an innovation. Potential adopters must not perceive significant advantage and reasonable fit, they must also believe that they can extract the benefits of an innovation without too much trouble (Leistner, 2010). If an innovation is not easy to implement then there is a risk that the payoff will never be achieved. Previous studies in the information systems field have found ease of use to be an essential factor in technology adoption decisions (Agarwal & Prasad, 1998; Ajzen, 1991). It is expected that software developers and operations workers who judge DevOps practices to be easy to use will form significant intentions to adopt. Therefore, this research concludes:

H8: Ease of use will have a significant, positive influence on adoption intention.

Trialability is expected to be significantly linked with adoption intention. The ability to demo or test an innovation on a limited basis has a significant impact on adoption intention (Agarwal & Prasad, 1997). By testing an innovation, individuals can perceive its fit, potential impact, and assess its value. These processes reduce uncertainty regarding the new concept and increase its acceptability. Trialability is often held to be more important for early adopters, because they have little precedent on which to make their adoption decision (Ettlie & O'Keefe, 1982). They must experiment with the concept in order to develop their attitudes toward the innovation. Thus, the following hypothesis is proposed:

H9: Trialability will have a significant, positive influence on adoption intention.

Finally, demonstrability of results is assumed to impact the decision to adopt an innovation. The results of adopting some innovations are easier to observe than others. Innovations which incorporate physical components or aspects are easier to observe than those which are strictly conceptual. Managerial innovations such as DevOps are not as easily observed because they consist of a series of practices for developing and maintaining software and ensuring high reliability. However, those who are able to observe its results are expected to have stronger adoption intentions (Bhattacherjee & Premkumar, 2004).

H10: Results demonstrability will have a significant, positive influence on adoption intention.

METHODS

Participants and Procedure

To examine differences in individuals' perceptions based on DevOps implementations, we used an experimental scenario design. We developed scenarios that depicted two distinct organizational development environments: one representing a traditional, mature development methodology with structured divisions of labor and another scenario describing a DevOps implementation. To prevent biasing our respondents, we did not mention the term "DevOps" in our DevOps scenario. The scenarios were analyzed for content validity and realism by an experienced senior software architect and a team of his colleagues.

Our survey was built using Qualtrics and distributed using Amazon Mechanical Turk (MTurk). Respondents were recruited based on being currently employed in a technology-oriented field where a DevOps implementation is possible (i.e. software developer, network engineer, programmer, web developer, system administrator, implementation expert, etc.). We recruited 500 technology workers to participate in the study. After following previously validated data cleansing guidelines for MTurk participants (Crump, McDonnell, & Gureckis, 2013; Steelman, Hammer, & Limayem, 2014), we achieved a final sample size of 391.

Measures

DevOps Implementation was operationalized as a binary variable. Half of the subjects were asked to consider a DevOps implementation at their work (1); the other half were not asked to consider the impact of a DevOps at their work (0). The scales for operationalizing the perception constructs were adopted from previously established measures (Moore & Benbasat, 1991). Relative advantage consisted of 5 measures; compatibility consisted of 3 measures; ease of use consisted of 3 measures; trialability included 3 items; results demonstrability included 2 items. All items were measured on 7 point scales. Respondent demographics, including age, gender, job title, and years of experience, were also captured before completion of the survey.

RESULTS

The structural model and its associated hypotheses were tested using SmartPLS (Ringle et al., 2005). According to Loch et al. (2003), convergent validity must be established to ensure that each item measuring a particular construct is significantly correlated with its construct's composite value. We followed the latest standards for establishing factorial validity in PLS (Gefen & Straub, 2005; Lowry & Gaskin, 2014). In examining PLS reports for cross-loadings, several items needed to be removed to establish convergent and discriminant validity (EOU1, EOU2, EOU3, RA4, RA8). In addition to item loadings above 0.70 on intended factors, an indicator of convergent validity is an average variance extracted (AVE) greater than 0.50 [15]. An AVE of 0.50 or greater was achieved on all constructs. With offending items removed, convergent validity was established for all constructs. The construct correlations, as well as crossloadings of measurement items, are shown in Table 1 and Table 2, respectively.

Table 1: Latent Construct Correlations

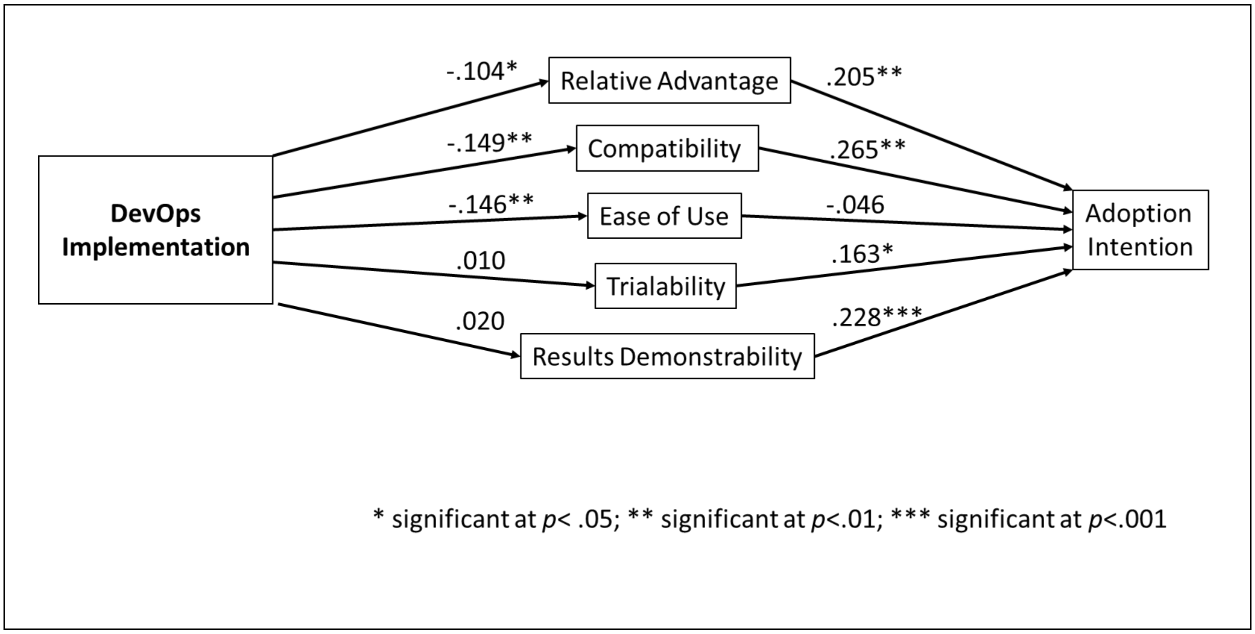
	AINT	COMP	DevOps	EOU	RA	RD	TRIAL
AINT	**(.922)**						
COMP	.658	**(.853)**					
DevOps	-.066	-.149	**(----)**				
EOU	.590	.794	-.146	**(.824)**			
RA	.635	.842	-.104	.795	**(.850)**		
RD	.602	.668	.020	.685	.604	**(.763)**	
TRIAL	.582	.639	.010	.650	.649	.644	**(.766)**

Square-root AVEs are shown in ( ) on the diagonal axis

Table 2: Crossloading, Reliability, and AVE								
	AINT	**COMP**	**EOU**	**RA**	**RD**	**TRIAL**	**Composite Reliability**	**AVE**
AINT1	.926	.636	.569	.607	.570	.517	.919	.849
AINT2	.917	.575	.516	.562	.539	.557		
COMP1	.555	.865	.675	.727	.567	.560	.914	.727
COMP2	.559	.827	.680	.695	.565	.547		
COMP3	.524	.854	.689	.732	.564	.510		
COMP4	.601	.865	.666	.720	.581	.561		
EOU4	.556	.696	.848	.690	.571	.588	.864	.679
EOU5	.495	.714	.862	.716	.601	.561		
EOU6	.387	.534	.759	.542	.520	.442		
RA1	.538	.686	.674	.830	.468	.560	.948	.722
RA2	.522	.735	.670	.868	.542	.577		
RA3	.552	.716	.723	.831	.530	.549		
RA5	.515	.698	.655	.858	.504	.523		
RA6	.517	.756	.692	.845	.525	.527		
RA7	.552	.692	.665	.862	.515	.552		
RA9	.575	.729	.649	.854	.507	.568		
RD1	.467	.442	.496	.444	.784	.458	.848	.582
RD2	.466	.587	.613	.555	.721	.524		
RD3	.442	.452	.445	.384	.753	.454		
RD4	.460	.555	.533	.454	.792	.526		
TRIAL1	.454	.493	.511	.540	.482	.749	.876	.587
TRIAL2	.438	.560	.576	.572	.494	.749		
TRIAL3	.446	.558	.548	.535	.541	.776		
TRIAL4	.423	.427	.435	.434	.481	.780		
TRIAL5	.467	.412	.422	.405	.467	.775		

A bootstrapping resampling technique, which approximates the path coefficients and the amount of variance explained in mediating variables, was utilized. Seven hypotheses were supported, while only three were not. The overall findings for hypothesis support are shown in Figure 1. The model explains 51.0% of the variance in intention to adopt DevOps. DevOps implementation had a significant effect on relative advantage ($\beta = -.104$, $p < .05$), compatibility ($\beta = -.149$, $p < .01$), and ease of use ($\beta = -.146$, $p < .01$). Adoption intention was significantly affected by relative advantage ($\beta = .205$, $p < .01$), compatibility ($\beta = .265$, $p < .01$), trialability ($\beta = .163$, $p < .05$), and results demonstrability ($\beta = .228$, $p < .001$). DevOps implementation did not demonstrate a significant effect on trialability ($\beta = .010$, $p > .05$) or results demonstrability ($\beta = .020$, $p > .05$). Ease of use did not significantly influence adoption intention ($\beta = -.046$, $p > .05$).

Figure 1: Structural Model & Path Weights



DISCUSSION

When technology employees were presented with a DevOps scenario, their perceptions of relative advantage, compatibility, and ease of use were significantly lower than the perceptions of those who were shown a scenario depicting a more traditional development framework. These findings further illustrate the challenges an organization faces when introducing DevOps to its employees. Developers and operators will perceive that there is not a significant advantage to using DevOps over existing frameworks, that DevOps is not compatible with the stable operations of the development team, and that DevOps presents a significant learning curve in comparison to a more traditional paradigm.

With the exception of ease of use, the innovation attributes demonstrated a significant positive effect on technology employees' intentions to adopt DevOps. The lack of relevance of ease of use may be explained by the higher explanatory power of results demonstrability, a related construct. This finding, in combination with the direct effects of DevOps implementation on innovation perceptions, seems to indicate that employees' perceptions of relative advantage and compatibility are the most critical barriers to adoption facing organizations. However, the introduction of DevOps in the workplace did not have an impact on trialability or results demonstrability, yet trialability and results demonstrability were still significant predictors of adoption intention. Prior work in DevOps research has often assumed negative perceptions of employees due to the drastic shift of roles within the organization (Leistner, 2010). Our data demonstrate that this is not the case for two key factors. These findings may offer a path to success for organizations interested in shifting to a DevOps framework. Research has shown that the maturity of a DevOps implementation has significant impacts on its success (Gupta et al., 2017). If employees can test the DevOps framework for certain projects and examine the results of such projects, they may be convinced to adopt DevOps for subsequent systems and work toward implementation maturity.

CONCLUSION

DevOps is an emerging trend which integrates software development and IT operations functions for improved communication, better software, quicker releases, and improved reliability. It also calls for a number of non-trivial organizational changes, some of which drastically change the scope and depth of employee responsibilities and authority. These changes may result in negative perceptions among employees. Before organizations adopt DevOps, they should consider their employees' attitudes. If employees do not have positive perceptions of DevOps, the implementation may not be successful. This research finds that four of five attributes of innovations are significant predictors of adoption intention. Relative advantage, compatibility, trialability, and results demonstrability were found to be significant predictors of adoption. Ease of use, although found to be relevant in related studies, was not significant in this study. However, this may be because DevOps' perceived ease of use was homogenously low among all subjects, giving little variance to be correlated. More research is needed to clarify this issue. However, it can be concluded that organizations which do not foster experimentation, trial, and testing among their employees will encounter reduced adoption intentions, emphasizing the importance of the organization's environment and vision in realizing successful DevOps implementation.

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