Advancing the Adoption of a New Generation of Certifications – A Theoretical Model to Explain the Adoption of Continuous Cloud Service Certification by Certification Authorities

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Abstract. Cloud certifications are a good means to assure users of high level of security and reliability of certified cloud services. However, cloud environments are highly dynamic due to the challenging cloud characteristics and fast technology life-cycles. We believe that current certifications fail to cope with an ever-changing cloud environment because assessments are based only on manual expert assessments and periodic spot checks. We argue that continuous service certification (CSC) is required to assure reliable and trustworthy cloud services. To understand and enhance CSC's rate of adoption, we examine the adoption process of CSC from the perspective of certification authorities by building on the Diffusion of Innovations theory and the Technology-Organization-Environment framework. Our findings reveal that the innovation's characteristics, organizational and environmental influences will affect the adoption of CSC by certification authorities. We advance the understanding of the CSC adoption process by providing a synthesis and discussion of important factors.

Keywords: Continuous Certification, Cloud Services, Diffusion of Innovations Theory, Technology-Organization-Environment Framework

1 Introduction

Several cloud service certifications have recently evolved and attempt to assure users of a high level of security, availability and legal compliance of the certified cloud service. Certifications aim to reduce cloud customers' concerns, increase trust as well as to enhance transparency in the cloud service markets. These cloud service markets have become increasingly popular because they offer a vast selection of IT services (e.g., online storage, office software and collaboration tools) that are instantly available and that can withstand unexpected fluctuations in demand for the service, e.g., quickly spin-

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ning up new resources when demand increases. Certifications in general are well-recognized means for organizations to assess goods and services [1, 2], and their importance and number steadily increase in recent years [3].

Yet, current research has primarily focused on identifying and assessing the effectiveness of certifications at a given point in time, and thus they are essentially regarded as static snapshots of attributes of providers and their services [4–6]. However, cloud service environments are highly dynamic, resulting from challenging cloud computing characteristics (e.g., on-demand provisioning and entangled supply chains), fast technology life cycles and ongoing architectural changes [6–8]. Likewise, cloud services are faced with dynamically emerging environmental challenges and with changes in legal landscape which might threaten certification effectiveness and reliability in the medium to long term.

We believe that current certifications fail to cope with an ever-changing cloud environment because certification assessments are based only on static, manual expert assessments and periodic spot checks, and may not be actually valid for longer periods of time since certification. Therefore, we argue that continuous service certification (CSC) is required to assure reliable and trustworthy certifications and cloud services.

CSC is beneficial for cloud certification authorities, service providers and customers altogether [7, 8]: certification authorities can actively detect and investigate critical certification deviations as they occur, thus increasing certification reliability over today's approaches; cloud providers can constantly improve their cloud services by evaluating ongoing feedback from certification authority about their performance; and finally CSC can counteract customers' worries due to lack of control of cloud infrastructure by increasing the transparency of providers' operation. With increasing reliance of organizations on cloud service providers, the necessity for continuous reliable, trustworthy and meaningful certification gains importance. Yet, CSC remains currently underexplored, not well test marketed and evaluated only in trials, resulting in a low adoption rate by certification authorities [8].

To understand and enhance CSC's rate of adoption, and therefore ultimately pave the way for continuously reliable and secure cloud services, we examine the adoption process of CSC from the perspective of certification authorities by conducting a thorough literature search, and building on the Diffusion of Innovations theory [9] and the Technology-Organization-Environment framework [10, 11]. Our work helps to answer the research question: *What influences certification authorities to adopt CSC?*

Investigating how the characteristics of an innovation as well as organizational and environmental factors will affect CSC's rate of adoption can be of great value to understand and enhance actual adoption processes [9]. With this study, we advance the understanding of the CSC adoption process by providing a synthesis and discussion of relevant factors that influence adoption rate of certification authorities. In addition, we provide a theoretical model to be tested in future research for validation.

The paper proceeds as follows. We provide a background on cloud service certifications and highlight the need for CSC, followed by a brief presentation of our research approach. Thereafter, we discuss how the characteristics of CSC, organizational, environmental, risk and cost factors influence the adoption process. We then discuss our findings and conclude with directions for future research.

2 Theoretical Background

2.1 Cloud Service Certifications

Cloud computing offers ubiquitous, on-demand access to a shared pool of configurable IT resources (e.g., servers, storage and applications) that can be rapidly provisioned and released with minimal management effort or service provider interaction [12]. On the one hand, cloud services offer an attractive alternative to traditional IT usage for organizations, and on the other hand they challenge contemporary security and privacy risk assessment approaches. Therefore, cloud services face a broad range of risks including lack of accessibility, reliability and virtualization vulnerabilities, privacy and control issues as well as issues related to data integrity and segregation [13].

One widespread strategy to reduce customers' uncertainties is to adopt certifications, which is particularly important for small and medium-sized cloud providers [1]. A certification is defined as a third party attestation of products, processes, systems or persons that verifies the conformity to specified requirements [14]. During a certification process, independent and accredited auditors perform comprehensive, manual checks to test adherence according to a defined set of certification criteria. If a provider adheres to the specified requirements, the certification authority awards a formal written certificate. A variety of certifications has already been developed and market tested to signal that providers have adopted their standards and comply with their certification audits; these exist particularly in cloud markets (e.g., EuroCloud *'StarAudit'* and Cloud Security Alliance *'Security, Trust & Assurance Registry'*). Cloud service certifications typically consist of security, privacy and reliability requirements, and build on IT standards (e.g., ISO 27001, ISO 27017 and ITIL), and aim to ensure availability, integrity and confidentiality of cloud services for a validity period of one to three years [15].

2.2 The Need for Continuous Certification

Existing certifications represent only a retrospective look at the fulfillment of technical and organizational measures. Requirements of certifications may no longer be met throughout the validity period of the certification because cloud services are confronted with continuously emerging environmental dynamics. Especially, we refer to environmental dynamics that are difficult to predict, lead to an instability and create uncertainty for customers or providers [16]. The premise behind these assumptions is that external environments impact organizational performance, and organizations must take into account environmental characteristics and emerging dynamics when formulating strategies and structures as well as during daily operations. As such, inherent cloud computing characteristics, ongoing architectural changes, the emergence of environmental threats or changes in legal and regulatory landscape can be regarded as dynamics that might have an impact on actions taken by a provider. Certification reliability has to be re-evaluated over time if the assumptions under which a certification was awarded have changed. Consequently, we believe that CSC is required to assure continuously reliable and trustworthy certification and cloud services. CSC is a methodology that enables

certification authorities to react and to adjust their certification reports simultaneously with the occurrence of events concerning the cloud service [6].

3 Research Approach

3.1 Literature Analysis

In this study, we focus on identifying factors that influence the adoption of CSC by certification authorities, and therefore conducted a thorough literature review. To find pertinent literature that deals with innovation adoption processes, we performed a search in the online database of EBSCOHost (Academic Search Complete and Business Source Complete). This search was executed on 15th March 2016 and was based on the following search string: *("Diffusion of Innovation*") AND (("Information System*") OR (IS))*, inspired by the Diffusion of Innovations theory [9]. The search was limited to title, abstract and keywords. Moreover, the results were reduced by applying the filters for only "peer-reviewed publications". This initial search revealed 81 potentially relevant articles, published from 1982 to 2015, which deal in different ways with the adoption or the diffusion of innovations. Some of these publications deal with innovations in general whereas others specifically refer to concrete innovations. By examining these articles, we determined 55 of them suggesting factors influencing the adoption of an innovation. Identified papers were read and factors impacting the adoption of an innovation were marked for further analysis, despite individual findings relating to the factors (i.e., regarding their empirical support) [17]; leading to 437 factors. As a lot of different factors were used in different articles, sometimes under different name, but we named them only once and noted their frequency of being mentioned, as this can be seen as an indicator of their importance. By this we reduced our list of factors to 258.

To further reduce this number of factors we carefully analyzed the used terms and their meaning. First, we identified synonyms, aggregated them into one factor and summed up the frequency of being mentioned for each of the synonymous terms. Second, we subsumed terms with similar meanings as for example *"competitors"*, *"competition"*, *"competitive advantage"*, and *"other industry players"* to *"competitive pressure"* and considered their total frequency of mention. Third, we excluded terms which, for example, refer to the adoption process itself rather than to factors influencing the adoption decision like *"earliness of adoption"*, and those terms which are referring to a concrete innovation, for example, *"website features"* and therefore cannot be transferred to CSC context. Finally, we carefully analyzed whether remaining factors are empirically supported and read research findings to ensure relevancy of factors. Based upon the remaining factors and on the frequency of being mentioned, we formed five groups of factors which have a major influence on the adoption of an innovation: *innovation's characteristics* (mentioned 124 times) including relative advantage, complexity, compatibility, observability and trialability; *organizational factors* (66) including organization, management and technology attributes; *individual factors* (49) including attitudes and skills; *environmental factors* (34) including the legal and regulatory landscape, market and competitive pressure; and finally *risks and costs* (16).

3.2 Theories of Factors Influencing the Adoption of Continuous Certification

The five groups of factors resulting from our literature analysis are in line with and can be assigned to two different theoretical models explaining the adoption of innovations: the Diffusion of Innovations theory (DOI) and the Technology-Organization-Environment (TOE) framework. The DOI theory was proposed by Everett M. Rogers [9] and focuses on why innovations – although having obvious advantages – are often very hesitantly adopted. A central concept of the DOI theory is the diffusion process, in which an innovation is communicated through certain channels, over time, among the members of a social system. Information about the innovation will be communicated during the diffusion process, which reduces uncertainty of potential adopters about the innovation itself, and finally leads to an adoption or rejection decision. An innovation is defined as an idea, practice or object that is perceived as new by an individual. The adoption rate is defined as the relative speed with which members of a social system adopt an innovation. While most research has concentrated on the adoption of innovations in regard to differences in their innovativeness, DOI theory examines the innovation itself, and how its characteristics affect its rate of adoption. DOI theory describes five main innovation characteristics: *relative advantage*, *compatibility*, *complexity*, *trialability* and *observability*. Literature shows that the DOI theory has a solid theoretical foundation and consistent empirical support (e.g., [18–20]). DOI theory focuses on the impact of innovation's characteristics, but acknowledges that the specific context, for example, the organization and her environment can influence the adoption rate as well [9, 21]. We integrate the TOE framework that serves as an important, additional theoretical perspective for studying such contextual factors [10, 11].

The TOE framework was developed by De Pietro, Wiarda and Fleischer [10], and is embedded into the research by Tornatzky and Fleischer [11] who describe the entire process of technological innovation, from the invention or development by engineers until the adoption and implementation by users within an organization. The TOE framework focuses on factors that influence the adoption and implementation of innovations in the context of an organization. It identifies three main contexts that influence the adoption of innovation: the technological, organizational and environmental context [10, 11]. The TOE framework has been used by researchers to examine the adoption of technological innovations, and has received ample empirical support (e.g., [20, 22, 23]).

To construct our theoretical model, we combined the DOI theory and the TOE framework by using the *innovation's characteristics* as representative factors for the *technological context.* In addition, we considered *organizational* factors, including both managerial and IT capabilities. We complemented them by *environmental factors* as well as the factor group '*risks and costs'* because they take a decisive influence with regard to the adoption of CSC (see Figure 1). We excluded the group of *'individual'* factors - although resulting from the literature research - because this study takes an organization

level perspective. Finally, we excluded *trialability* as one of the innovation's characteristics because CSC cannot be tested easily beforehand as it affords high efforts and expenditures.

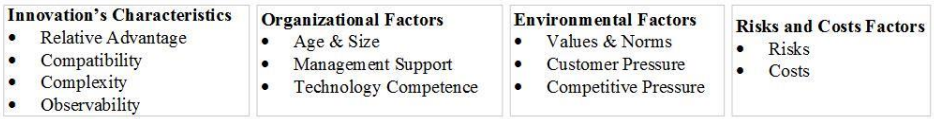

Figure 1. Factors influencing the adoption of CSC.

4 Theoretical Model of Factors and their Impact on the Adoption of Continuous Certification

In the following, we discuss identified factors in regard to the adoption of CSC by certification authorities, derive propositions about their impact and integrate them into a theoretical model.

Innovation's characteristics exert a great influence on the adoption of an innovation. Before an organization passes through the innovation-decision process, it seeks information in order to decrease uncertainty about the relative advantage of an innovation [9]. Such a *relative advantage,* which for example generates cost savings or offers the solution to an existing problem, can lead to the adoption of an innovation because it is perceived as better, more economic or expediently. Providing CSC services is beneficial for certification authorities because CSC increases their efficiency and reliability of issued certifications in particular.

In the context of traditional certification processes, adherence to certification requirements is observed by spot checks on a yearly basis only. Hence, certification deviations might be detected lately or hardly ever. In contrast, CSC allows the certification authority to actively detect critical defects as they occur. Hence, CSC can be considered as proactive and enables corrective actions as soon as a problem is detected. So CSC can improve reliability and trustworthiness of issued certifications. In addition, certification reports are more relevant to customer's decision makers. The change from yearly spot checks to CSC is often accompanied by the use of automated certification processes which enable certification authorities to test larger data samples and examine data in a faster and therefore more efficient way, compared to their manual predecessors. Finally, the certification authority might gain further benefits by offering innovative certification services for cloud customers and charging extra fees (e.g., enabling customers to validate requirement adherence on demand). While in traditional certification contexts a business relationship only exists between the cloud provider and the certification authority, CSC enables certification authorities to build up a direct relationship with cloud service customers, hence, creating new business models. Consequently, CSC provides significant relative advantages for certification authorities because it increases the efficiency and quality of certifications, enables new business models, and leads to continuously secure and reliable cloud services.

Proposition 1 (P1): Relative advantages foster the adoption of CSC by certification authorities.

The more *compatible* an innovation is perceived with sociocultural values and beliefs, the needs of potential adopters or with previous experiences the less uncertainty concerning the innovation is present; leading to a higher rate of adoption [9]. Certifications are well-recognized means for customers to assess goods and services [1]. Importance and number of independent third party product and service assessments steadily increase in recent years [3]. Yet, providers are threatened by a highly dynamic and ever-changing environment, and thus quickly respond to emerging environmental dynamics. With increasing reliance of customers on cloud services their demand for continuous, highly reliable and secure services gains importance. Consequently, it is necessary for the certification authority to continuously verify the conformity with certification requirements.

Previously introduced ideas and practices are a familiar standard against which the innovation can be interpreted [9]. Current certification practices are mostly based upon manual auditing operations, for example, performing interviews and manual security tests. The transition to CSC requires an automation of certification processes. The use of computer-based audit tools and technologies (CAATTs), which already aims at automating processes and facilitating the certification authority's work, could therefore promote this transition. Nonetheless, surveys reveal that CAATTs are not yet frequently and systematically used [24], although they are seen as useful and beneficial. We assume that CSC is compatible with the needs of relevant stakeholders and previously introduced ideas leading to a positive effect on the adoption.

P2: A high compatibility fosters the adoption of CSC by certification authorities.

The *complexity* of an innovation is measured by the degree to which the innovation is perceived as relatively difficult to understand and use [9]. The higher the complexity is, the greater is the uncertainty of potential adopters. Adopting CSC exhibits a high degree of complexity. Certification authorities must establish CSC and management systems to support the certification planning, management, operation and scheduling activities, develop new certification processes and train their employees. In order to reduce the complexity of the CSC, authorities can build on existing monitoring systems and processes of the provider to gather certification-relevant data [25]. For example, certification authorities might access an interface that enables the secure and reliable transmission of relevant data. Further on, the authority has not only to manage his own CSC operations, but also has to consider and align with providers' ongoing activities, which also increases the complexity of CSC. Consequently, the certification scope has to be adjusted individually for each cloud service, for example, in regard to available cloud systems, provider's organizational size, the number of employees as well as the level of technical knowledge and skills.

P3: A high complexity hampers the adoption of CSC by certification authorities.

The *observability* is the degree to which the innovation provides tangible results [9]. The higher the perceived observability of an innovation is, the more positively it affects the adoption rate. Performing CSC aims to increase transparency about cloud service operation and certification adherence. Results of CSC will be visible for the public, for example, by ongoing certification reports. In order to further increase the observability, CSC offers the means for a new generation of web assurance seals: dynamic, up-to-date, and accurate seals informing customers about the actual certification requirement

adherence status. Creating a high transparency for cloud service customers promotes the observability of CSC and has a positive effect on its adoption rate. However, a high observability also places high burdens on the protection and anonymization of provided data to ensure data confidentiality, integrity and authenticity.

P4: A high observability fosters the adoption of CSC by certification authorities.

Organizational factors comprise features and characteristics of the organization, essential aspects of management as well as the extent and the level of use of technology; factors that influence the adoption of an innovation [10, 11]. An organization is characterized by its *age* and *size* among others. Since size represents several important aspects of an organization, such as slack resources, organizational structure and decision-making flexibility, it is a critical factor to influence innovation adoption [9]. In the IS literature different opinions exist regarding the role that size plays [20]. On the one hand, large and established authorities may be less flexible than smaller and younger organizations, might show less innovation readiness and rather insist on previously applied methods [20, 23]. But on the other hand, these authorities have access to profound experience and knowledge about certification processes and emerging innovations, and can build on more financial means and multifarious human and material resources in order to meet challenges posed by the adoption of innovations [9, 20]. We assume that certification authority's size and age will foster the adoption of the CSC because they generally possess slack resources and expertise to meet adoption challenges, including high initial investments and the redesign of certification business processes.

P5: The certification authority's size and age will foster the adoption of the CSC.

With respect to organization's *management*, its settings, policies and priorities in particular affect the adoption of innovations [10, 11]. Thus, for example, CSC adoption should be consistent with organizational objectives and strategy [21] and supported by the top management [26]. The top management should provide the vision, support and commitment around the innovation as well as commit resources and create the environment required for the adoption [27]. Thus, top management exerts a positive influence on the adoption of CSC.

P6: Management support fosters the adoption of CSC by certification authorities.

Further on, the certification authority's *technology competence* has an influence on the innovation adoption [10, 11, 20]. Technology competence refers to the technological characteristics available in the organization such as the IT infrastructure and IT professionals [23]. The IT infrastructure covers the installed technologies, systems and applications within the certification authority allowing an integration of CSC services and corresponding IT systems. IT professionals are the human resources with technical knowledge required to efficiently perform CSC. For example, if the existing IT infrastructure is highly developed and versatile, and supports the integration of new CSC components, adoption uncertainty is reduced and adoption rate increases.

P7: Technology competence fosters the adoption of CSC by certification authorities.

Environmental factors comprise environmental values and norms, customer and competitive pressures [10, 11]. The *environmental values and norms* can affect the adoption of CSC for example by changing or setting up new guidelines. If for example the validity period of cloud certificates is generally shortened, this prepares the transi-

tion to the CSC and could ultimately effect that certification authorities are only accredited when awarding their certificates based on CSC. Also the government can contribute to the adoption of CSC when well-reputed government institutions highlight the use of CSC as an effective way to increase the security and reliability of cloud services.
P8: The values and norms foster the adoption of CSC by certification authorities.

Cloud customer pressure can exert great influence on the adoption of CSC [9–11]. Certification authorities might start adopting CSC, for example, if an ever-increasing amount of (potential) cloud customers demands reliable certifications in modern, turbulent environments. In the future, customers might decide whether to use a cloud service or not, based on providers' willingness to be continuously certified. Consequently, customer pressure is assumed to be of great influence on the adoption of CSC.
P9: Customer pressure fosters adoption of CSC by certification authorities.

Certification authorities compete for certification requests. *Competitive pressure* also acts as a facilitator influencing the adoption of CSC. Either the incentive of first mover competitive advantages or the urgency to keep up with competitors will provide the focus and purpose to successfully overcome obstacles and resistance to innovation adoption within an organization [21, 28]. Likewise, innovation imposition strategies by providers and partners might foster adoption rate of CSC, for example, if cloud providers tend to engage only with certification authorities that apply CSC in order to fulfill the demands of their cloud customers. Subsequently, competitive pressure might force certification authorities to open up for CSC and to create necessary conditions for adoption.
P10: Competitive pressure fosters the adoption of CSC by certification authorities.

Risk and cost factors are referring to possible disadvantages or dangers, and to expenses, which may affect the adoption of an innovation. In general, risks and costs represent multi-dimensional constructs that need to be viewed from different angles and analyzed in detail. For example, various security and privacy risks might emerge that impact certification authorities' adoption intention differently. CSC implies the transmission and storage of data about the cloud service at the site of the certification authority. Subsequently, certification authorities are becoming a valuable target of attackers from the outside. Hence, this involves high risks of data theft, leads to significantly higher demands on data security and data protection, and may hamper the adoption.
P11: Risks hamper the adoption of CSC by certification authorities.

CSC of cloud services usually goes with automation of processes which on the one hand affords high expenditures for purchasing the technical equipment and a high amount of running costs for the operation and maintenance. On the other hand, an automation of processes might lead to (mid-term) cost savings.
P12: Costs influence the adoption of CSC by certification authorities.

Figure 2 depicts our theoretical model and summarizes identified factors and their impact on the adoption intention of CSC by certification authorities. Adoption intention refers to the probability that an organization will adopt CSC processes, set up required IT infrastructures, and provide CSC services for cloud providers.

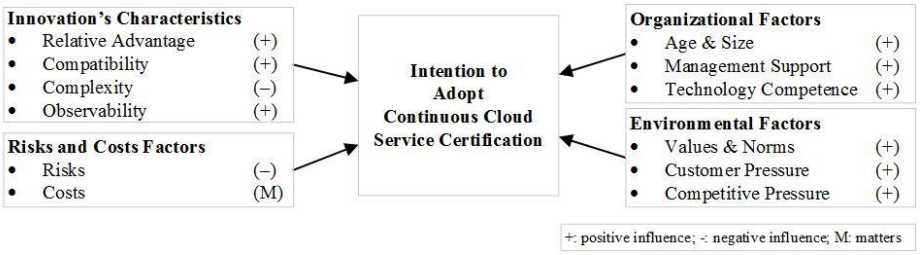

Figure 2. Theoretical model of CSC adoption by certification authorities.

5 Discussion and Conclusion

Based on a literature analysis, we developed a theoretical model by integrating the DOI theory and the TOE framework complemented by risk and cost factors to examine which factors influence the adoption of continuous cloud service certification. Thereby, we are able to analyze the adoption of an innovation from two different perspectives: the innovation itself with its characteristics and the surrounding organizational and environmental contexts. This study shows that many factors have an important impact on the adoption of CSC. We believe that the multifarious relative advantages of CSC and a high degree of observability will strongly motivate certification authorities to adopt CSC. On the other hand, a limited compatibility and a high complexity might hamper adoption. In regard to organizational factors, top management support and a high technical competence will positively influence the adoption of CSC. As environmental factors, customer and competitive pressures are of great importance when adopting CSC of cloud services. At last, risks and costs are relevant inhibitors for the adoption of CSC.

The identified and discussed factors have been considered separately, but some are closely related to each other, which might result in moderating effects on the adoption intention. First, relative advantages of CSC – due to a high observability of CSC results – are visible for both cloud customers and competitors, and thus they can lead to an increase of customer and competitive pressure as environmental factors. Second, a high technological competence, for example, due to the existence of a well-equipped IT department with well-trained specialists, reduces the complexity of CSC as well as increases innovation's compatibility. Finally, a close interrelationship between environmental pressures as well as perceived relative advantages, and top management support is apparent because they influence the strategy of an organization and actions that are preferred by the management.

With this study, we provide a two-fold contribution for research and practice. First, we advance the understanding of the CSC adoption process by providing a synthesis and discussion of relevant factors that influence adoption rate from a DOI and TOE perspective. Investigating how the attributes of an innovation affect its rate of adoption can be of great value to change agents seeking to predict the reactions to an innovation, and perhaps to modify certain of these reactions by the way they name and position an innovation [9]. Finally, we provide a theoretical model to be tested in future research to validate our assumptions, and to enhance the adoption process.

Nevertheless, this study has some limitations. Our discussion of the factors is based on literature analysis and theoretical reasoning research only since at the current diffusion state only a minority of certification authorities have started to deal with CSC adoption. However, we are currently working on a quantitative study to analyze to what extent the discussed factors influence CSC adoption. Within this study we focused on the adoption of CSC of cloud services by certification authorities, hence our theoretical model might be limited in regard to the context of cloud services as well as for the certification authorities as stakeholder. Finally, we neglected factors of individual adopters (i.e., managers) which might be of great importance in the actual adoption decision process.

"Last, […] an innovation's rate of adoption is affected by the extent of change agents' promotion efforts" [9]. On this account, we want to encourage researchers and practitioners with this study to participate in adopting and diffusing CSC.

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