IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received September 12, 2018, accepted October 23, 2018, date of publication October 30, 2018,
date of current version December 31, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2878798

Assessing the Determinants of Adopting Component-Based Development in a Global Context: A Client-Vendor Analysis

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This work was supported by the Deanship of Scientific Research at the King Fahd University of Petroleum and Minerals, Saudi Arabia, under Grant IN151016.

ABSTRACT Component-based software (CBS) development is an attractive proposition to globally distributed software development organizations because of its potential to integrate reusable components in new products. Several organizations have adopted CBS development practices to support their global development processes, a phenomenon referred to as globally distributed CBS development. Many factors influence an organization's decision to adopt globally distributed CBS development practices. The objective of this paper is to systematically assess the determinants that influence the adoption of CBS development practices in global software development organizations. We develop a conceptual research model based on the diffusion of innovation theory and the technology-organization-environment framework. Data collected from 115 participants are used to test the conceptual model. The findings from our study indicate that relative advantage, complexity, technology competence, and top management support are the key determinants for organizations to adopt globally distributed CBS development practices. The assessment of both the direct and total effects of the determinants offers insight into the organization's decision to adopt globally distributed CBS development practices.

INDEX TERMS Component-based development, diffusion of innovation theory, global software development, technology-organization-environment framework.

I. INTRODUCTION

Component-based software (CBS) [1] and global software development (GSD) [2], [3] are two methodologies that have attracted the attention of the software industry due to their potential to reduce development costs and produce quality systems. CBS development focuses on the development of reusable components and assembles existing software components to build a software system [1]. The GSD methodology is defined as: "the process where a company (client) contracts all or part of its software development activities to another company (vendor), who provides services in return for financial compensation" [2].

Several globally distributed software development organizations have adopted CBS practices to capitalize on a number of benefits [3], [4]. For example, CBS development can facilitate globally distributed software development by assigning ownership of particular components to different geographical sites and as a result reduce inter-site communication and coordination [5]. Similarly, on the other hand, globally distributed CBS projects jointly develop components in different sites and hence, gain access to expertise regardless of its geographical location. In addition to the benefits of globally distributed software development, a few challenges have also been reported in [6]–[8]. For example, Holmstrom *et al.* [9], Damian *et al.* [10], and Kotlarsky *et al.* [11] have reported difficulties in managing CBS projects in a global context due to a lack of standards and issues related to the granularity of components.

Although researchers have shown interest in understanding the globally distributed CBS development methodology, existing studies have focused on the technical and operational issues. Few studies have addressed the adoption of globally distributed CBS development from an organizational perspective. Furthermore, few studies have done an evaluation of the effects of the determinants on globally distributed CBS development adoption.

The objective of this study is to identify the determinants that influence organizations to adopt the CBS development methodology in global software development projects. The motivation of our work is to identify both the direct and indirect effects of the determinants on the adoption of the globally distributed CBS development approach from an organizational perspective. Identifying these determinants will assist globally distributed software development organizations to be ready for global CBS development projects. To do this, we address the following research questions:

- RQ1: What are the determinants of adopting CBS development in a global software development project?
- RQ2: What are the direct and indirect effects of the determinants of adopting CBS development in a global software development project?
- RQ3: What are the differences, if any, between the determinants of adopting CBS development in a global software development project related to client and vendor organizations?

To address these research questions, we develop a research model that integrates the diffusion of innovation (DOI) theory and the technology-organization-environment (TOE) framework to assess the effects of the determinants of adopting the globally distributed CBS development methodology. This study has two main contributions: first, we assess the direct and indirect effects of the DOI and the TOE characteristics on the adoption of globally distributed CBS development practices in an organization. Second, our study presents an assessment of the determinants of the globally distributed CBS development methodology from both client and vendor perspectives. Hence, the study provides insight into the organization's decision to adopt globally distributed CBS development methodology.

The remainder of this paper is organized as follows: Section 2 describes the background work. In Section 3, we discuss our research model and hypotheses. Section 4 describes our research methodology. Section 5 describes the results. In Section 6, we present the implications of the study results and its limitations and discuss how the findings from this study can be further used in future research endeavors. Finally, Section 7 presents the conclusion of the study.

II. BACKGROUND

A. GLOBALLY DISTRIBUTED CBS DEVELOPMENT

In order to develop quality software in a cost effective manner, organizations are adopting globally distributed software development projects [3], [5], [11]. Global software development is defined as: ''development carried out by teams of knowledge workers located in various parts of the globe who develop commercially viable software for a company'' [2], [12]. The software industry is interested in implementing global software development due to its economic and technical benefits [3], [13], [14]. For example, an advantage of global software development is the potential reduction in the project life cycle by using 'follow-the-sun' development [15], [16]. Organizations are also interested in tapping into skilled resources available at geographically distributed sites. Furthermore, global software development allows offshore vendor-site organizations to improve their service quality [17]. Despite the benefits of GSD, there are numerous challenges in the globally distributed context, such as geographical, temporal and cultural differences which affects software development in terms of communication, coordination, and control processes [14], [18], [19], and there are also some risks for GSD teams such as the distribution of knowledge sharing and knowledge management between sites [9]–[11].

Component-based software development involves the development of software components and building software applications through the integration of pre-existing software components [1], [20], [21]. CBS development offers the advantage of the systematic reuse of existing components to help improve the productivity and quality of software products. However, the main challenge associated with CBS development is that it takes longer to develop a component that can be reused in a number of products [3], [22].

Several organizations have adopted CBS development practices to support their global development processes [3], [5], [18]. CBS development is an attractive proposition to globally distributed software development organizations because of its potential to reuse components in new applications [3], [5]. In addition to setting up reuse-based software development, globally distributed development organizations adopt the CBS development methodology to mitigate the risk of coordination breakdowns encountered in non-CBS globally distributed software development [5], [23]. On the other hand, the globally distributed CBS development methodology also faces challenges due to a lack of reuse standards and issues related to the granularity and generality of components.

B. ADOPTION MODELS

The diffusion of innovation theory [24] and the technology-organization-environment framework [25] are frequently used adoption theories to assess the determinants of adopting technology in studies of innovation diffusion. Some other theories that are applicable to an individual's choice such as the theory of planned behavior (TPB) [26] and the technology acceptance model (TAM) [27] are not examined in this research study.

Diffusion of innovation [24] is a common adoption theory in information systems (IS) research. Five characteristics have been identified which assist an organization to adopt a technology [35], [39], [41], [43], [53], [54]. These are: first, relative advantage, an innovation's degree of attractiveness to the organization over other existing innovations being used in the organization; second, compatibility, an innovation's degree of flexibility in relation to the organization's existing processes, practices and ongoing requirements; third, complexity, an innovation's degree of intricacy and complication to the organization's use and operations; fourth, trialability, an innovation's degree of simplicity in terms of experiments with the innovation in the organization; fifth, observability,

TABLE 1. Constructs for Research Models in Peer Reviewed Journals.

Study	Year	Theory	Innovation/technology	Constructs a.	b.	c.	d.	e.	f.	g.	h.	i.	j.
[28]	2017	DOI and TOE	Cloud computing adoption	X	X	X					X	X	X
[29]	2017	DOI and TOE	Mobile applications adoption	X	X	X					X		X
[30]	2017	DOI and TOE	E-pubic procurement adoption	X								X	X
[31]	2017	DOI and TOE	Cloud service certifications adoption	X	X	X	X		X		X		X
[32]	2016	DOI and TOE	Green IT adoption									X	X
[33]	2016	DOI and TOE	Adoption of SaaS	X	X	X	X		X		X		X
[34]	2014	DOI and TOE	Cloud computing adoption	X	X	X	X	X			X		X
[35]	2011	DOI and TOE	Internet and E-business adoption	X	X	X					X	X	X
[36]	2011	DOI and TOE	Cloud computing adoption	X	X	X		X					X
[37]	2010	DOI and TOE	Information technology adoption			X				X			
[38]	2010	TOE and others	E-business adoption					X				X	X
[39]	2010	DOI and TOE	Effective benchmarking adoption	X	X	X			X	X		X	
[40]	2009	DOI and TOE	Adoption of enterprise systems	X	X	X					X	X	X
[41]	2009	DOI and TOE	Adoption of the Internet				X		X		X		
[42]	2009	DOI and TOE	Adoption of c-commerce	X	X	X					X		X
[43]	2006	DOI and TOE	E-business use	X	X	X	X		X				X
[44]	2012	DOI	Electronic purchasing applications		X					X			
[45]	2010	DOI	Intention to RFID adoption	X			X				X	X	
[46]	2017	TOE	Information technology adoption		X		X		X		X		X
[47]	2017	TOE	E-health adoption								X	X	
[48]	2016	TOE	Mobile reservation system adoption	X	X				X		X		X
[49]	2012	TOE	Adoption of Open-source Software	X			X						
[50]	2011	TOE	RFID adoption study			X	X				X		X
[51]	2011	TOE	Adoption of E-commerce	X			X						X
[52]	2008	TOE	E-business adoption									X	X
[53]	2004	TOE	Open Source platform adoption	X	X		X		X	X			

Note: a. Relative Advantage; b. Compatibility; c. Complexity; d. Cost Savings; e. Technology Readiness; f. Technology Competence; g. Availability of Alternatives; h. Top Management Support; i. Organizational Readiness; j. Competitive Pressure.

an innovation's degree of visibility to employees of the organization [34], [35], [43].

The TOE framework allows organizations to better understand the procedure of introducing an innovation in an organizational context [25]. Three factors influence an organization's adoption of a new technology. These are: first, the technological context which includes the technological capabilities, features, attributes and/or essential qualities of the host organization; second, the organizational context which includes the resources and characteristics of an organization such as its size, degree of centralization, managerial structure etc. that help in the adoption and implementation of an innovation; and third, the environmental context, which includes forces beyond the control of the organization, such as competitors and the nature of the market from a product-production point-of-view [25], [37], [38], [55], [56]. Moreover, the technological characteristics of an organization include human resources and structural aspects [34].

C. INTEGRATING DOI AND TOE

A growing number of researchers study the potential of innovation adoption by integrating more than one theoretical approach [34], [37], [57]–[59]. Innovation adoption studies commonly integrate the DOI theory and the TOE framework, an approach that is supported by several empirical studies. Although there are many similarities between both theories, there are also many differences. The TOE framework does not provide any suggestion for some innovation characteristics such as complexity [35], observability [34], compatibility [43], trialability [34], and individual [37] etc., whereas the DOI theory does not describe the role of some innovation characteristics such as technological readiness [38], application functionality [34], technology competence [41], [43], availability of alternatives [37], top management support [35], firm size [60], degree of centralization [53], organizational readiness [38], competitive pressure [34], regulatory support [37], [60] etc. Therefore, the integrative model addresses the shortcomings of each and helps to provide a comprehensive view to an organization about adopting an innovation. Table 1 presents the determinants used in different adoption studies.

D. NEED FOR THIS EMPIRICAL STUDY

Few researchers have reported empirical evidence on the technical and management issues associated with globally distributed CBS development. For example, Repenning *et al.* [61] highlight that the CBS development approach is suited to distributed software development and suggest that each site should take ownership of components independently to reduce inter-site communication and coordination. Turnlund [62] suggests that the independent ownership of components will facilitate the reduction of inter-site coordination and hence, will help organizations to realize the benefits of globally distributed CBS development.

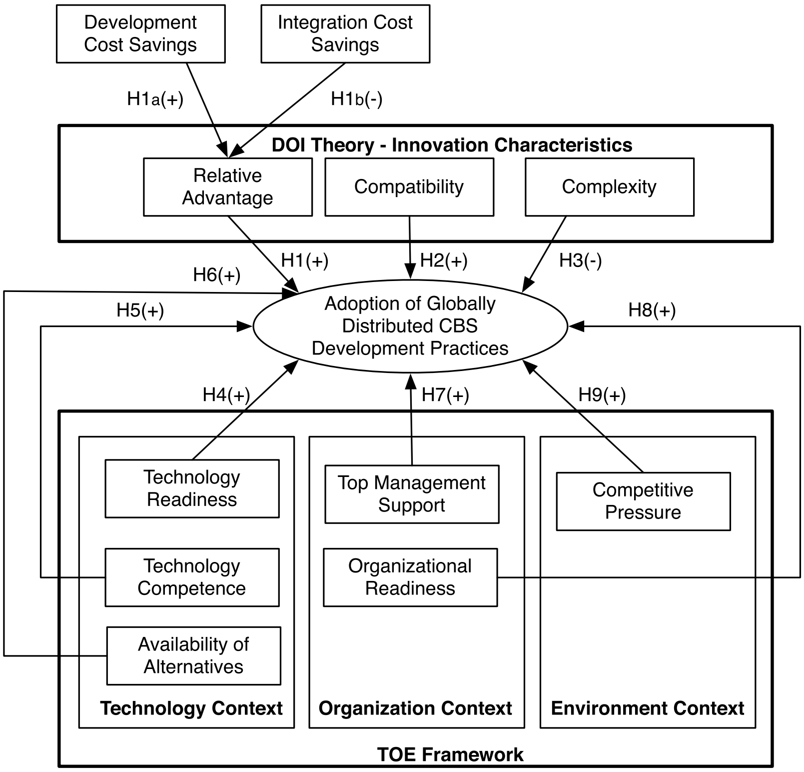

FIGURE 1. Research Model for Globally Distributed CBS Development Adoption.

Oshri and Sue [63] discuss the knowledge process viewpoint of globally distributed CBS development and show that knowledge embedded in a component's design can be contextual and requires communication between teams before being applied to another product. On the other hand, Kotlarsky and Oshri [3] and Kotlarsky *et al.* [5] indicate that globally distributed CBS projects can improve the reuse of components by developing individual components in a joint manner by utilizing expertise regardless of different site locations.

However, few studies have been conducted to systematically assess the determinants that influence the adoption of a CBS development methodology in the global software development context. Such a study is important for both practitioners and researchers to better understand the current state of industry in the context of adopting a CBS development methodology in a GSD project. The study uses a research model based on two adoption theories to uncover the determinants that assist organizations to adopt a CBS development methodology in global projects. Furthermore, we also provide evidence as to how the CBS development determinants, as identified in the research model, relate to client and vendor perspectives of a globally distributed organization.

III. RESEARCH MODEL AND HYPOTHESES

The objective of this paper is to systematically assess the determinants that influence the adoption of CBS development practices in the global software development context at the organization level. We develop a research model that uses the DOI theory and TOE framework to determine the factors of globally distributed CBS development adoption at the organization level. The use of both DOI and TOE theoretical models to assess technology adoption at an organization level has received empirical support as other study results indicate that the combination of two theoretical models helps improve the ability of the research model to explain IT adoption [33], [34]. Hence, we combine the DOI theory and the TOE framework to provide a theoretical basis to assess the determinants at the organization level that influence globally distributed CBS development adoption. The integrative research model is shown in Figure 1.

A. DOI THEORY HYPOTHESES

Relative advantage is defined as the "degree to which an innovation is perceived as being able to provide better organizational benefit than the idea it supersedes" [24]. Relative advantage is a key driver of new methodology adoption by an organization [33], [34]. One of key advantages of globally distributed CBS development is the possibility to reuse components and reduce project life cycle by using time-zone differences to implement the 'follow-the-sun' development model [5]. Therefore, we propose the following hypothesis:

H1: Relative advantage positively influences the adoption of globally distributed CBS development practices.

CBS development is an attractive proposition to globally distributed teams because the reuse of in-house components in a number of different products leads to lower development cost for an organization [3]. Furthermore, organizations can also purchase commercial-off-the-shelf components as an alternative to in-house development for a lower price than in-house development costs. Therefore, we propose the following hypothesis:

H1a: Development cost savings positively influence the relative advantage of adopting globally distributed CBS development practices.

Component integration is a critical phase because individual components are rarely ready for a direct 'plug and play'. The CBS integration process often requires developers to write glue-code to manage the mismatches between requirements and component features. Hence, the component integration cost becomes an issue in a globally distributed environment due to the challenges associated with inter-site knowledge sharing, communication and coordination. Therefore, we propose the following hypothesis:

H1b: Integration cost savings negatively influence the relative advantage of adopting globally distributed CBS development practices.

Compatibility is defined as ''the degree to which the innovation fits with the potential adopter's existing values, practices and current needs'' [24]. Compatibility is a key determinant of innovation adoption [33], [34]. For example, if the aim of adopting CBS development practices in a global context is to take advantage of reusing existing components, either developed in-house or purchased commercial off the shelf, then using CBS development methodology makes economic sense. Hence, compatibility will determine whether globally distributed CBS development will be adopted by an organization. Therefore, we propose the following hypothesis:

H2: Compatibility positively influences adoption of globally distributed CBS development practices.

Complexity is defined as ''degree to which an innovation is perceived to be relatively difficult to understand and use'' [24]. The chance of technology adoption increases when it is easier to integrate the technology into business operations [34]. CBS development practices offer the ability to reuse components developed at different geographical sites. However, the complexity of managing the coordination of work carried out by all involved sites will increase. Therefore, we propose the following hypothesis:

H3: Complexity negatively influences the adoption of globally distributed CBS development practices.

B. TOE FRAMEWORK HYPOTHESES

1) THE TECHNOLOGY CONTEXT

Technology readiness is defined as ''the technological characteristics available in the organization for the adoption of technology including both structural aspects and the specialized human resources'' [34]. Global development organizations with a range of collaborative tools available for their global teams are more likely to have the effective communication and coordination required for developing and reusing components.

Similarly, organizations with standardized design practices across sites will facilitate a greater reuse rate of components [23]. Hence, organizations with a higher degree of technological readiness are better suited for adopting CBS development practices in a global context. Therefore, we propose the following hypothesis:

H4: Technology readiness positively influences the adoption of globally distributed CBS development practices.

Technological competence is defined as ''the technological characteristics with reference to the skill set of the professionals available in an organization'' [41], [43], [60]. Globally distributed CBS development projects need skilled teams with experience in managing inter-site communication and coordination as well as expertise in design-for-reuse strategies. We believe that an organization with higher technology competence will be prepared to adopt globally distributed CBS development practices [3], [7]. Therefore, we propose the following hypothesis:

H5: Technology competence positively influences the adoption of globally distributed CBS development practices.

In the technological context of the TOE framework, the availability of alternatives gives a positive direction and standing to an organization for adopting an emerging technology [37]. If the technological characteristics of an innovation are open to the use of other available alternatives, then this technology is more beneficial and advantageous for adoption by the organization [39]. In globally distributed CBS development, components are operated independently in remote locations without inter-site coordination and communication issues, and each site can hold a particular component without an ownership issue [3]. The standardization of some components and processes specifically for reuse will give a clear understanding for working on them across remote sites, independently [23]. CBS development, being an emerging innovation, gives the freedom to use available standard components as alternatives in the adopted environment, such as the global context in this case. Therefore, we propose the following hypothesis:

H6: The availability of alternatives positively influences the adoption of globally distributed CBS development practices.

2) THE ORGANIZATION CONTEXT

Top management support is referred to as ''the vision, support and commitment provided to foster the desired environment for the adoption of new innovation'' [33]. The adoption of globally distributed CBS development practices will introduce changes in an organization's structure, especially with reference to the facilitation of inter-site team reachability, interactions, expanding the collective knowledge of the dispersed team and investing in designing for reuse. Since the adoption of globally distributed CBS development practices is a key decision, top management will positively influence

TABLE 2. Sample characteristics (N = 115)

Company	Company area	Destination	Size	NP	Respondent's position
1	Software consultancy	Australia	medium	9	IS manager, project manager, senior software engineer
2	Software consultancy	Australia	medium	9	system analyst, team leader
3	Software consultancy	Australia	medium	9	team leader, project manager, IS manager
4	CBS development house	Australia	medium	9	system analyst, team leader
5	CBS development house	Australia	medium	8	team leader, project manager, IS manager
6	IT department	Australia	medium	8	senior project manager, senior software engineer
7	CBS development house	Australia	medium	7	IS manager, project manager, senior software engineer
8	CBS development house	Australia	small	5	senior software engineer, project manager
9	IT department	Australia	small	5	team leader
10	IT department	Saudi Arabia	medium	10	project manager, software engineer, IS manager
11	IT department	United Arab Emirates	medium	9	system analyst, team leader
12	CBS development house	Pakistan	medium	9	project manager, IS manager
13	CBS development house	India	small	7	project lead, team leader
14	IT department	Malaysia	small	4	team leader
15	IT department	Saudi Arabia	small	3	team leader
16	Software consultancy	South Korea	small	3	senior project manager, senior software engineer
17	CBS development house	China	small	1	project manager

Note: Number of Participant (NP).

its adoption in an organization. Therefore, we propose the following hypothesis:

H7: Top management support positively influences the adoption of globally distributed CBS development practices.

Although organizational readiness is a sub-category of organizational context, it also refers to the combination of two contexts of the TOE framework i.e. the technology context and the organization context [25], [38]. As an organizational context determinant for change, it also refers to the change commitment of the members of the organization and their shared belief of implementing a change using an innovation [64], and to the necessity of the available organizational resources to adopt an innovation [35]. For successful CBS development adoption in the GSD context, organizations need to standardize and manage social ties such as creating and maintaining the team environment, building relationships, facilitating interactions, and component management such as designing for reuse, investment in advanced development, facilitating reuse, and managing vendors [3], [6], [23]. CBS development, being an IT innovation, gives an opportunity to standardize practices and processes through the collective involvement of the employees of an organization. Hence, we propose the following hypothesis:

H8: Organizational readiness positively influences the adoption of globally distributed CBS development practices.

3) THE ENVIRONMENT CONTEXT

The key to understanding the objectives of an organization is to manage its environmental context, which relates to the internal strategies and processes for conducting the firm's business. The environmental context includes the nature of the market, the competitors in the market and takes a product-production point-of-view approach to other market resources [55]. It is also influenced by entrepreneurial culture [34], market structure [37], [39], perceived environmental barriers [34], competitive pressure [34], [35], [38], [39], [43], [60], technical support services [39], regulatory support [34], [37], [39], and relevant technology support [37], [39].

Competitive pressure is defined as "the pressure felt by a firm from industry competitors" [38], [65]. Adopting new development methodology is sometimes a strategic necessity to compete with respective competitors. By adopting globally distributed CBS development, organizations potentially benefit from shorter time-to-market, access to skilled human resources at a relatively low cost and systemic component reuse. Therefore, we propose the following hypothesis:

H9: Competitive pressure positively influences the adoption of globally distributed CBS development practices.

IV. RESEARCH METHODOLOGY

A. MEASUREMENTS

A questionnaire survey was developed to ask industry practitioners about the determinants that influence CBS development adoption in GSD organizations. We developed a closed format online questionnaire survey as the data collection instrument to collect data from a range of experts in the IT industry who are involved in CBS development in global software development projects. The questionnaire was built based on the determinants described in our research model shown in Fig 1. Table 2 presents a summary of the study participants. Each determinant has a minimum of two and a maximum of three measurement items, as shown in Table 3.

The survey was tested using a pilot study involving thirteen practitioners from three different organizations. Based on the pilot study, the final version of the survey was developed. The survey consists of three sections: section one collects demographic data, section two asks participants to rate

TABLE 3. Measurement Items for GD CBS Development

Constructs	Items	Adopted Source
Development cost savings	DC1 – The use of CBSD allows you to reduce the costs involved in developing new products.	[3], [5], [7], [22]
	DC2 – The use of CBSD allows to have a reduction in maintenance cost.	
Integration cost savings	IC1 – The expertise required to integrate components is usually costly.	[3], [18], [23]
	IC2 – Using CBSD requires more efforts while integrating components.	
	IC3 – With CBSD there is an increase in integration cost over time.	
Relative advantage	RA1 – CB system is easy to use and effective to maintain because of components.	[7], [22], [23]
	RA2 – Using CBSD allows you to reduce process risk.	
	RA3 – The use of CBSD offers standardize components.	
Compatibility	CPT1 – The use of CBSD is compatible with your current development process of the organization.	[5], [11]
	CPT2 – The use of CBSD will reduce the knowledge and information dependencies in the organization.	
	CPT3 – The use of CBSD is compatible with existing applications develop at remote sites.	
Complexity	CX1 – The use of CBSD requires more efforts in finding suitable components.	[3], [18], [22], [23]
	CX2 – The skills needed in integration testing of the product is a challenge in CBSD.	
	CX3 – The adoption of CBSD is not progressive with limited skills for management of components.	
Technology readiness	TR1 – The preparedness of employees who have the knowledge of CBSD.	[18], [23]
	TR2 – The knowledge of the company about how to support development activities by using CBSD.	
	TR3 – The company know the benefits gain by the replacement of existing modules with pre-fabricated components.	
Technology competence	TC1 – For adoption of CBSD, our company have enough human resources and IT infrastructure items.	[3], [18], [23]
	TC2 – Our company's technological capabilities are enough to accomplish IT projects with CBSD.	
Availability of Alternatives	AA1 – The use of CBSD allows to operate components independently in remote locations.	[3], [23]
	AA2 – The use of CBSD gives a freedom of using available alternative components.	
Top management support	TMS1 – The implementation of CBSD is managed by the firm's management support.	[3], [11]
	TMS2 – For the adoption of CBSD, our organization's management is ready to take risks (i.e. financially and organizationally).	
Organizational Readiness	OR1 – Our company has a shared belief towards implementation of a change by using CBSD.	[3], [6]
	OR2 – The skills needed for managing social ties (i.e. interactions, team atmosphere, relationships) and component management is available in the firm.	
Competitive pressure	CP1 – Organization believe that CBSD has an impact on competition.	[3], [7]
	CP2 – For the adoption of CBSD our company is under pressure from competitors.	
	CP3 – CBSD is already being adopted by some of our competitors in the market.	
CBSD adoption	CBSD1 – "At what stage of CBSD adoption is your organization currently engaged? Not considering; Currently evaluating (e.g., in a pilot study); Have evaluated, but do not plan to adopt this technology; Have evaluated and plan to adopt this technology; Have already adopted processes, practices or infrastructure of Component-based Software Development."	[50]
	CBSD2 – "If you are forecasting that your company will adopt CBSD in the future. How do you think it will happen? Not considering; More than 5 years; Between 2 and 5 years; Between 1 and 2 years; Less that 1year; Have already adopted processes, practices or infrastructure of Component-based Software Development."	

each determinant; and section three includes an open-ended question that provides an opportunity for participants to share their experience regarding determinants that affect the adoption of global CBS development practices in their respective organizations. The confidentiality of the participants was ensured as the raw data was only accessible to the research team and the team will not share the data in a way that could reveal a participant's individual or organizations identify.

B. DATA COLLECTION

In this research, the target population of the survey was practitioners with more than three years of experience in using CBS development practices in a global software development organization. The 'key informant' technique [66] was used to identify the practitioners who are knowledgeable about the adoption of CBS development practices in the global context. An initial invitation to participate in the study was sent to the potential participants via LinkedIn groups and industrial contacts of the software engineering research group at King Fahd University of Petroleum and Minerals. Participants at a management level in their organizations served as contact points for the study. The contact points were emailed the survey, which they were asked to forward to invite other relevant participants in their professional network, as this would help provide characterization of an unknown population [67], [68].

The online survey with a brief explanation of the study scope was emailed to qualified participants. Data was collected in one phase from March 2017 to September 2017. A total of 380 participants were contacted. A total of 126 responses were received. The completed surveys were manually reviewed and subsequently 11 surveys were excluded due to incomplete data. As a result, the analysis was performed over 115 valid responses. The study has a response rate of 30%, which is comparable to similar studies [60].

TABLE 4. Mean, Standard Deviation and Reliability Indicators

Constructs	Mean	SD	AVE	CR
Development cost savings	3.83	0.51	0.704	0.824
Integration cost savings	3.89	0.54	0.734	0.891
Relative advantage	3.79	0.55	0.653	0.849
Compatibility	3.66	0.72	0.698	0.873
Complexity	4.00	0.76	0.584	0.807
Technology readiness	3.64	0.65	0.793	0.919
Technology competence	3.79	0.87	0.677	0.805
Availability of alternatives	3.87	0.66	0.855	0.922
Top management support	3.94	0.59	0.668	0.800
Organizational readiness	3.99	0.61	0.837	0.911
Competitive pressure	3.73	0.50	0.678	0.861
CBS development adoption	3.73	0.37	0.980	0.990

Note: Standard deviation (SD), average variance extracted (AVE), and composite reliability (CR).

41% of the responses were from small and 59% were from medium-sized organizations. The mean, standard deviation and reliability indicators are shown in Table 4.

V. RESULTS

In this section, we present the results for the conceptual research model shown in Fig. 1. Path modeling analysis, a variance-based technique [69], was used to analyze the data through PLS-SEM (partial least squares - structural equation modeling) [70]. We have used PLS-SEM because it helps explain the variance in the dependent variables of a research model. The use of PLS estimation requires two conditions to be satisfied: (1) the minimum sample size should be 10 times the largest number of indicator variables used to measure one latent variable; or (2) in a structural model, the minimum sample size should be 10 times the largest number of structural paths directed at a latent variable [34], [71]. Our data satisfies these two basic conditions for the use of PLS estimation. SmartPLS is used to evaluate the validity and reliability of the measurement model [70], [71].

The reliability and validity results for our measurement model are shown in Table 4. Composite reliability (CR) was used to test the reliability of the scales. The CR results for all constructs are greater than 0.7, which confirms the reliability of the scales [69]. The convergent validity was ensured by checking the average variance extracted (AVE). As all constructs in the measurement model have an AVE greater than 0.5, this confirms the convergent validity [72]. This indicates that the construct explains more than 50% of the variance of its indicator variables [72]. All measurement items were evaluated for indicator reliability such that they have a loading greater than 0.7 and are at significance level 0.01 (except three that are at significance level 0.05), as shown in Table 9 in Appendix. This means indicator reliability is good, so we retained all measurement items.

Moreover, two measures were used for the assessment of the discriminant validity of the constructs i.e. Fornell-Larcker criteria and cross-loadings. To confirm the Fornell-Larcker criterion, it is necessary that all the correlations between the latent variables should be less than the square root of the AVE of the latent variables [72]. In our case, the correlation between the pair of latent variables is less than the square root of AVE as shown in Table 5, so this criterion is confirmed. To confirm the cross-loadings criterion, it is necessary that all cross-loadings should be less than the loadings of each indicator variable [73]. The resulting crossloadings and loadings indicate that the cross-loadings are less than the loadings (tables available on request from the authors), so the cross-loadings' criterion is confirmed. Hence, these measures confirmed the discriminant validity. All these assessments confirm that the latent variables can be used for further evaluation of the research model.

A. STRUCTURAL MODEL ANALYSIS (RQ1AND RQ2)

To confirm there are no concerns about multicollinearity, the variance inflation factors (VIF) are used. The traditional threshold is 5. If the latent variables have a VIF less than 5, then there is no multicollinearity. In our case, VIF for most of the latent variables is less than 3 and for some latent variables it is less than 5, which confirms the VIF show that there is no multicollinearity among the latent variables. Furthermore, standard paths were examined for the analysis of the hypotheses of our identified determinants for globally distributed CBS development adoption (RQ1). A bootstrapping method (with 500 re-samples) was used to assess the path significance levels. The resulting path coefficients along with the other analyses are summarized in Table 6 (RQ2).

The results show that the effect of development cost savings ($\beta = 0.22$; $p < 0.05$) on relative advantage is statistically significant (β is the path coefficient). Hence, the hypothesis that development cost savings as an independent latent variable for relative advantage of GD CBS development (H1a) is confirmed ($p < 0.05$). Similarly, the results also show that the effect of integration cost savings ($\beta = 0.40$; $p < 0.01$) on relative advantage is statistically significant. Thus, the hypothesis that integration cost savings as an independent latent variable for relative advantage of GD CBS development (H1b) is confirmed ($p < 0.01$).

To evaluate the influence of the other constructs of the TOE framework, the effects of technology competence ($\beta = 0.21$; $p < 0.05$) and top management support ($\beta = 0.08$; $p < 0.05$) are statistically significant for an explanation of GD CBS development adoption, whereas the effect of technology readiness ($\beta = 0.04$; $p > 0.05$), availability of alternatives ($\beta = -0.03$; $p > 0.05$), organizational readiness ($\beta = 0.13$; $p > 0.05$) and competitive pressure (_= −0.02; $p > 0.05$) are not statistically significant (RQ2). Thus, the hypotheses for technology competence (H5) ($p < 0.05$) and top management support (H7) ($p < 0.05$) are confirmed, whereas they are not confirmed for technology readiness (H4), availability of alternatives (H6), organizational readiness (H8) and competitive pressure (H9) ($p > 0.05$) (RQ1 and RQ2).

In the research model, the indirect effect of development cost savings on globally distributed CBS development

TABLE 5. Correlations of the Constructs and AVEs

Constructs	a	b	c	d	e	f	g	h	i	j	k	l
a. Development cost savings	**0.839**											
b. Integration cost savings	0.154	**0.857**										
c. Relative Advantage	0.282	0.437	**0.808**									
d. Compatibility	-0.061	-0.107	-0.121	**0.836**								
e. Complexity	0.227	0.432	0.559	-0.066	**0.764**							
f. Technology Readiness	0.036	0.000	0.087	-0.038	-0.032	**0.890**						
g. Technology Competence	0.113	0.561	0.736	-0.107	0.708	0.060	**0.823**					
h. Availability of Alternatives	0.218	0.530	0.723	-0.152	0.689	0.061	0.786	**0.925**				
i. Top Management Support	0.114	0.526	0.409	-0.110	0.535	0.077	0.485	0.480	**0.817**			
j. Organizational Readiness	0.137	0.527	0.722	-0.135	0.704	0.088	0.800	0.816	0.555	**0.915**		
k. Competitive Pressure	0.083	0.128	0.132	-0.060	0.064	-0.259	0.193	0.117	0.106	0.087	**0.823**	
l. CBS Development Adoption	0.192	0.483	0.734	-0.094	0.858	0.084	0.820	0.758	0.588	0.808	0.076	**0.990**

Note: The square root of AVE for each construct is the diagonal.

TABLE 6. Research Model Constructs

Constructs	Path coeff.	T-Stat.	P-Value
Determinants of relative advantage of CBS development adoption in global context (direct effects)			
Development cost savings	0.220	2.529	0.012
Integration cost savings	0.403	4.333	0.000
		$R^2 = 0.225$	
CBS development adoption in global context determinants (direct effects)			
Relative advantage	0.206	3.468	0.001
Compatibility	0.007	0.159	0.874
Complexity	0.484	5.437	0.000
Technology readiness	0.047	1.453	0.147
Technology competence	0.210	2.408	0.016
Availability of alternatives	-0.038	0.661	0.509
Top management support	0.088	2.235	0.026
Organizational readiness	0.132	1.661	0.097
Competitive pressure	-0.027	0.667	0.505
CBS development adoption in global context determinants (indirect effects)			
Development cost savings	0.045	1.990	0.047
Integration cost savings	0.083	2.786	0.006
		$R^2 = 0.858$	

Note: Path Coefficient (Path coeff.), T-Statistic (T-Stat.).

adoption is calculated by multiplying the path coefficients of development cost savings (which explains relative advantage) and relative advantage (which explains GD CBS development adoption). Therefore, the multiplication of path coefficients (0.22∗0.20) is 0.044. To assess the influence of development cost savings on GD CBS development adoption, the indirect effect of development cost savings ($\beta = 0.04$; $p < 0.05$) on GD CBS development adoption is statistically significant (RQ2). Thus, the indirect effect of development cost savings on globally distributed CBS development is confirmed ($p < 0.05$) (RQ1 and RQ2).

Similarly, to assess the influence of integration cost savings on globally distributed CBS development adoption, the indirect effect of integration cost savings ($\beta = 0.08$; $p < 0.01$) on GD CBS development adoption is statistically significant (RQ2). Hence, the indirect effect of integration cost savings on globally distributed CBS development is confirmed ($p < 0.01$) (RQ1 and RQ2). The integrative research model explains 85% of CBS development adoption in the GSD context. The results of our analysis show the significance of the integrative research model to explain the adoption of CBS development in a global software development project.

B. CLIENT VENDOR BASED ANALYSIS (RQ3)

In order to provide more insights to researchers and practitioners, we performed client-vendor based analysis over the collected data on all the determinants and organizational background of the participants, which was requested in the demographic field of the questionnaire survey, filtering if a participant is a client or a vendor in GSD. The collected data reflect the experience of the participants working in GSD-based project organizations from a client and vendor perspective. In order to find whether there is a significant relationship between the two categorical variables, such as a client and vendor from a single population (R3), we applied

TABLE 7. Chi Square Test Results for Client Vendor Data

Constructs	Occurance in survey (n = 115)										Chi Square (linear by linear association) alpha = 0.05		
	Client (n = 42)					Vendor (n = 73)							
	SA	A	N	D	SD	SA	A	N	D	SD	X2	Df	P-Value
Development cost savings	23	9	6	3	1	48	14	4	5	2	2.165	1	0.141
Integration cost savings	15	16	3	4	4	29	30	1	6	7	0.955	1	0.328
Relative advantage	19	10	7	5	1	24	24	9	11	5	3.000	1	0.083
Compatibility	16	12	5	6	3	26	23	9	7	8	0.468	1	0.497
Complexity	**16**	**16**	**6**	**2**	**2**	**31**	**25**	**6**	**5**	**6**	**5.453**	**1**	**0.019**
Technology readiness	17	11	5	6	3	22	24	11	8	8	1.662	1	0.197
Technology competence	**13**	**18**	**8**	**3**	**0**	**28**	**18**	**17**	**9**	**1**	**4.270**	**1**	**0.038**
Availability of alternatives	16	16	8	1	1	27	24	8	7	7	0.810	1	0.368
Top management support	25	6	6	5	0	42	14	8	9	0	0.631	1	0.426
Organizational readiness	**17**	**19**	**5**	**0**	**1**	**28**	**24**	**12**	**5**	**4**	**3.875**	**1**	**0.049**
Competitive pressure	19	8	4	10	1	27	20	8	15	3	1.217	1	0.271

the chi-square test of independence and the results are shown in Table 7. Therefore, we propose the following hypothesis:

Null Hypothesis: There is no significant association between the identified GD CBS development determinants from a GSD client vendor perspective.

The findings in Table 7, which compare GD CBS development determinants from a GSD client vendor perspective, show that there are more similarities than differences among the respondents of our questionnaire survey (R3). Moreover, the findings also show that there are three significant differences (i.e., $p < 0.05$) among GSD organizations from a client vendor perspective. The p-Value of development cost savings, integration cost savings, relative advantage, compatibility, technology readiness, availability of alternatives, top management support, and competitive pressure is not less than 0.05, therefore, we accept the null hypothesis and conclude that these GD CBS development determinants are independent of the client vendor perspective of the GSD environment (R3). Nevertheless, the p-Values of complexity, technology competence and organizational readiness determinants are 0.019, 0.038 and 0.049, respectively. Despite the fact that many globally distributed CBS development determinants do not show statistical difference, the p-Values for complexity, technology competence and organizational readiness determinants are less than 0.05, therefore, our findings show significant differences for these three determinants and we reject our null hypothesis (R3). It is interesting to note that practitioners from client organizations (either strongly agreed or agreed, 76Similarly, practitioners from client organizations (either strongly agreed or agreed, 74%) and vendor organizations (either strongly agreed or agreed, 63%) indicate that 'technology competence' is an important determinant for CBS development adoption in GSD projects and also that it is more important to client-side rather than vendor-side organizations. More interestingly, practitioners from client-side organizations (either strongly agreed or agreed 86%) and vendor-side organizations (either strongly agreed or agreed 71%) indicate that 'organizational readiness' is an important determinant for CBS development adoption in GSD projects. The client vendor-based analysis is summarized in Table 7.

VI. DISCUSSION

A. THEORETICAL IMPLICATIONS

The study presented in this paper makes important contributions to the globally distributed CBS development literature. First, research has highlighted the need for holistic empirical studies that integrate different theoretical perspectives for the study of IT innovation [33], [34]. Hence, in this study, we incorporate two well-known adoption theories (i.e. DOI theory and TOE framework) for the study of globally distributed CBS development practice adoption. We use an integrative approach to use the innovation characteristics from the DOI theory and three TOE framework perspectives to develop a research model to assess the determinants of adopting CBS development practices in a global context.

Second, no study has been conducted to holistically assess the direct and indirect effects of the characteristics of globally distributed CBS development adoption and the underlying organization, environment and technology context. This study addresses a research gap and contributes to the body of knowledge on the adoption of CBS development practices in a global context. Furthermore, this study also finds that client and vendor organizations have different determinants for adopting globally distributed CBS development practices. In addition to filling this important research gap, the findings of our study serve to enhance the awareness of organizations of the effects of the determinants that influence the adoption of CBS development practices in client and vendor organizations.

B. PRACTICAL IMPLICATIONS

Relative advantage (H1), a dependent construct of development cost savings and integration cost savings, has a positive influence on globally distributed CBS development in the GSD context. Globally distributed organizations adopt CBS development to enhance the benefits that they are obtaining from the existing development practices [5]. The study also shows that globally distributed firms recognize the relative advantage of CBS development methodology (RQ1). To comprehend the influence of development cost savings and integration cost savings on globally distributed CBS development in the GSD context, we evaluated the constructs. The results showed that development cost savings positively influence and integration cost savings negatively influence the adoption of globally distributed CBS development in GD organizations (RQ1). Globally distributed organizations prefer to adopt GD CBS development due to a reduction in development cost, shorter time-to-market and use of COTS components [7]. For example, one of the participants supported his response to the cost determinant with the following comment:

"We introduced components, building as well as using COTS components, to our organization's development activities and kept in mind that this will potentially reduce development cost. Now, I am in a position to advise others to get cost benefits for their organization's development activities." Senior Project Manager

Integration cost savings is a determinant that negatively influences CBS development in a global context and the participants agreed that the expertise required to integrate components is usually costly. Nevertheless, they also agreed that the integration process of the components in CBS development requires great effort. For example, one of the participant expresses his viewpoint with the following comment:

"All sites of our organization usually follow pre-defined strategies for integrating commercial-off-the-shelf (COTS) software components. Apart from this, we also have experts available at each site who have experience in integrating and managing components, but still we are in a vulnerable position due to requests for instant changes to software components in the software industry." IT manager

Similar to development cost savings, the participants agreed that relative advantage is a key determinant and development activities with globally distributed CBS development are easy to use and effective to maintain because of standardized components. Two of the participants with the following comments also supports this determinant:

"I am excited to let you know that we have a pool of components in our organization that helps us in performing our tasks more quickly." Senior Software Engineer

"Component-based development is easy due to the fact that it requires customization most of the time. The components meet the standards for most of the development activities. I personally feel it is easy when adding some components that would have been provided by my colleague sitting in another site of the organization for the ongoing project." Team Leader

Complexity (H3) has a negative influence on globally distributed CBS development adoption in the GSD context (RQ1). Globally distributed organizations have challenges, such as geographical, temporal and cultural differences that affect software development activities in terms of communication, coordination and control [18]. The participants indicated that it is difficult and requires great effort to find suitable components when integrating components to form a large system.

"I am not sure if it is really important to others but I will not adopt CBS development unless I have a reference architecture at hand to support my development activities for a successful project." Project Manager

"Our company has been very successful in developing small software projects with a CBS development methodology for years but when it comes to integrating components for a large software product, it somehow fails to deliver the product on its scheduled time. I believe it is a challenge for large software projects in CBS development." Team Leader

Technology competence (H5) has a positive influence on CBS development in the GSD context (RQ1). For example, one of the participants commented:

"The expectations for adopting CBS development are high when employees of the organization have sufficient skills and knowledge in the use of CBS development methodology to deploy globally successful software development projects. Our organization has enough technological capabilities to allow us to use global CBS development in all sites." Project Manager

The results of our study also indicate that top management support (H7) has a positive influence on globally distributed CBS development adoption in GSD organizations (RQ1). Top-level management help and support the organization by allowing the use of CBS development in all sites of the organization. For example, one of the participants commented:

"We intend to seek support from top-level management prior to adopting a development methodology for our development activities; therefore, it is an essential factor in the adoption process." Senior Software Engineer

In a nutshell, the practical recommendations for globally distributed CBS development practitioners are as follows:

- *To avoid complexity, GSD managers should assign the component selection task to teams who have knowledge and skills in understanding the need for appropriate components.*
- *GSD organizations need to create a repository of reusable components in order to realize the benefits of GD CBS development in the long run.*
- *GSD project managers should provide a mechanism for knowledge sharing among component developers at each site in GD organizations.*
- *The importance of the GD CBS development methodology and its relative advantages should be manifest to management in order to elicit support from top management.*
- *GSD project managers should have a unified standard for developing and using components in multiple software products across geographically distributed sites and it will potentially reduce development cost.*

C. ORGANIZATION SIZE BASED ANALYSIS

Organization-size-based analysis of the identified determinants gives researchers and practitioners a deeper insight into

TABLE 8. Summary results based on organization size based analysis

Respondents' organization size	No. of significant determinants (cited as strongly agree by >= 50% of participants)
Small (n = 28)	6 determinants: Development cost savings Integration cost savings Relative advantage Complexity Top management support Competitive pressure
Medium (n = 87)	2 determinants: Development cost savings Top management support

the results at hand; therefore, we analyzed the significant determinants based on the size of the target organizations. This allows us to place the respondents of our questionnaire survey into different groups such as 'small' and 'medium', defined by the size of the organizations as shown in Table 8. An organization was considered small if it had less than 20 employees, whereas an organization was considered to be of medium size if it had 20 to 199 employees.

Development cost savings and top management support were significant determinants for small and medium GSD organizations. However, the respondents from small GSD organizations agree that other determinants, such as integration cost savings, relative advantage; complexity and competitive pressure were significant. It is imperative to mention that the findings depicted in Table 8 do not provide any room for the relative importance of these determinants from different viewpoints in this study; rather it depicts the significance of these determinants from different viewpoints.

D. LIMITATIONS AND FUTURE DIRECTIONS

There are a few limitations in this study that have potential for future research. First, the sample is limited to organizations in Australia and Asia. This implies that this study only shows the situation in these nations. In a future study, we plan to do a comparative study of organizations based in Europe and North America. Since this study does not consider the use of open source and inner source components, a future study can assess whether this distinction produces different results. Furthermore, organizations adopting globally distributed CBS development practices use a variety of software development processes ranging from the tradition waterfall process to the agile development process.

This study does not provide a longitudinal perspective on the relationship between different software development processes and their impact on determinants to adopt CBS development in a global context. We suggest new research models are developed to study the impact of software processes on the adoption of globally distributed CBS development practices. One other possible limitation is the number of determinants, as there is possibility more determinants that could explain the adoption activity. Therefore, researchers can add other determinants such as firm size, degree of centralization, and

TABLE 9. PLS loadings for GD CBS Development

Items	Loading	T-statistics	P-Values
DC1	0.713	3.053	0.002
DC2	0.949	8.551	0.000
IC1	0.910	31.855	0.000
IC2	0.725	8.391	0.000
IC3	0.922	35.074	0.000
RA1	0.712	11.813	0.000
RA2	0.816	20.138	0.000
RA3	0.887	31.516	0.000
CPT1	0.927	2.949	0.003
CPT2	0.808	2.955	0.003
CPT3	0.764	2.590	0.010
CX1	0.706	8.753	0.000
CX2	0.757	14.297	0.000
CX3	0.824	16.554	0.000
TR1	0.718	2.667	0.008
TR2	0.961	4.190	0.000
TR3	0.969	4.248	0.000
TC1	0.719	10.675	0.000
TC2	0.915	46.659	0.000
AA1	0.940	58.945	0.000
AA2	0.909	26.521	0.000
TMS1	0.740	9.632	0.000
TMS2	0.888	23.662	0.000
OR1	0.901	22.669	0.000
OR2	0.929	52.266	0.000
CP1	0.728	2.600	0.010
CP2	0.723	2.328	0.020
CP3	0.990	3.715	0.000
CBSD1	0.990	375.871	0.000
CBSD2	0.990	388.966	0.000

Note: All items are based on five-point scale except those noted otherwise.

regulatory support in their research to better understand the determinants of CBS development from an organization perspective. Lastly, the proposed research model can be further evaluated not only for the adoption stage.

VII. CONCLUSION

Several globally distributed software development organizations have adopted CBS practices to capitalize on a number of benefits such as reduced development cost, time-to-market and increased overall quality of systems. This paper identifies the determinants that influence the adoption of globally distributed CBS development in a GSD project context. The study provides a holistic evaluation of both direct and indirect effects of the determinants of adopting globally distributed CBS development practices from an organizational perspective.

The findings of our study indicate that relative advantage, complexity, technology competence and top management support are key determinants for organizations to adopt globally distributed CBS development practices. The study also indicates the direct effects of development cost savings and integration cost savings on the relative advantage of globally distributed CBS adoption and the indirect effects of development cost savings and integration cost savings on globally distributed CBS adoption. Furthermore, the study shows that evaluating new technologies for adoption such as the adoption of globally distributed CBS development, a systematic approach that combines the characteristics of the adopting innovation and technological, organizational, and environmental perspectives of the organization is trustworthy in explaining the perceptions to researchers and practitioners.

APPENDIX
PLS LOADING DATA

See Table 9.

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