An Empirical Investigation of Geographically Distributed Agile Development: The Agile Enterprise Architecture Is a Communication Enabler

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ABSTRACT Agile software development performance depends on active communication. Active communication is an arduous task when agile teams are geographically distributed. Agile enterprise architecture was reported to enhance such active communication and performance. There is little empirical evidence on how agile enterprise architecture can enhance communication and performance of geographically distributed software development. This paper contributes to this research gap by empirically examining the relationships between agile enterprise architecture, active communication, and performance (on-time completion, on-budget completion, software functionality, and software quality). Using a quantitative data analysis approach, the PLS results of survey responses of 160 research participants suggest that agile enterprise architecture has positive effects on active communication, on-budget completion, functionality, and quality. The results also indicate that communication efficiency has positive effects on on-time and on-budget completion; while communication effectiveness has positive effects on functionality, quality, and on-budget completion.

I. INTRODUCTION

The combination of geographically distributed development and industry-strength agile practices [1], [2], known as GDAD, seems to offer many benefits, such as low production cost, the opportunity to involve the most talented developers around the world, and faster time to market [3], [4]. GDAD refers to the agile development that includes teams and/or team members distributed over different locations [3], [5]. Accordingly, GDAD teams or team members can be locally distributed in different physical locations within the same country or can be globally distributed around the globe in different time zones or different countries [3], [6], [7].

Despite the abovementioned lucrative benefits, GDAD also involves many challenges [8], [9], especially communication-related challenges [10]–[13]. The Comprehensive Human Appraisal for Originating Software (CHAOS) report is a

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study run by the Standish Group that measures the information technology project success rate based on three requirements; on-time, on-budget and on scope [14]. The CHAOS report that was released in 2016 and covers the years between 2011 and 2015 shows that 23% of the software projects that used GDAD have failed compared to 4% that used co-located agile development [14]. Another survey by Scott Ambler on success factors of agile development shows that greater is the level of geographic distribution, greater is the risk due to communication and coordination challenges resulting in lower success rate [15]. Communication challenges refer to the characteristics of each medium that decrease communication efficiency and effectiveness [16]. Many challenges of GDAD communication were identified in the literature such as distance differences, time-zone differences, culture differences, project domain, and process management [10], [17]. Herbsleb and Mockus [18] argue that the project in a globally distributed development environment takes 2.5 times more time than the same project in the local non-distributed

environment due to poor communication (e.g., delivering an incomplete, inaccurate or inadequate message).

Communication is considered vital in the co-located agile development teams to overcome the uncertainty and changeable customer's requirements [19], [20]. Communication is important and challenging in GDAD because there are fewer opportunities for face-to-face communication and a larger number of interdependent teams and projects. Therefore, there is a big need to study and enhance communication for better GDAD performance. Hence, this paper focuses on empirically investigating how to enhance GDAD communication. There were few published empirical sources found in the literature, despite communication is considered the key enabler of GDAD performance [21], [22],

Moreover, literature has reported that agile enterprise architecture (AEA) artifacts or models can enhance GDAD communication [23]. Also, using AEA can enhance GDAD performance and onboarding new developers, although it will add a level of formality [24], [25]. Moreover, insufficient control in GDAD may lead to less product-market match [26]. In this paper, AEA is defined as the enterprise architecture (EA) that implements agile principles and focuses on collaboratively and incrementally developing, adapting and sharing information about business and IT mode in order to effectively guide the implementation of an agile project [23]. Nevertheless, there is little empirical evidence to support this claim either. Thus, there is a need to empirically examine how AEA can affect GDAD communication and GDAD performance [27].

This paper aims to fill the above literature gap by addressing critical questions relating to AEA, GDAD communication, and GDAD performance. Hence, this paper addresses the following research questions:

RQ1: How does AEA affect GDAD communication?

RQ2: How does AEA affect GDAD performance?

RQ3: How does GDAD communication affect GDAD performance?

To answer the above research questions and test hypotheses between AEA, GDAD communication, and GDAD performance, we used a quantitative data analysis approach. We conducted a PLS analysis of the data collected from a survey questionnaire of individuals in 160 AEA driven GDAD organizations (i.e. GDAD organizations that use AEA in their development).

The main contributions of the paper are as follows. Firstly, while both AEA and agile software development require more empirical evidence and theoretical underpinnings that support their claimed benefits and key principles [23], [28], the first contribution of this paper lies in its theoretical model [29], [30]. This paper provides a novel nomological model of the relationships among AEA, GDAD active communication, and GDAD performance.

Secondly, this paper examines if AEA can enhance GDAD active communication and GDAD performance. AEA model provides a holistic and integrated view of the business and technology architecture of an enterprise, which can be communicated as a knowledge base for guiding the development and implementation of project specifics solution architectures and roadmaps. AEA model evolves as the different agile projects and their architectures are developed and implemented in small iterations. AEA model could be seen as a holistic blueprint to guide the teams working on different interdependent projects in the GDAD. AEA model can be analyzed from a number of aspects. However, the scope of this paper is only limited to address the "communication" aspect of the GDAD through AEA model. AEA seems attractive to enhance GDAD communication and GDAD performance [25], [27], [31]; however, as indicated earlier, this hypothesis requires empirical evidence. Hence, this paper addresses this important gap and empirically investigates the impact of AEA on GDAD communication and performance (RQ1 and RQ2). The findings of this paper show a significant impact of AEA on communication efficiency, communication effectiveness, on-budget completion, functionality, and quality; however, it does not show a significant impact on on-time completion.

Thirdly, this paper distinguishes and investigates the multidimensional nature of communication. This has not been explicitly established or examined in the prior agile development. Two dimensions of agile development communication were identified; communication efficiency and communication effectiveness. The Agile Manifesto states that the "most efficient and effective method of conveying information to and within a development team is face-to-face conversation" [1]. Thus, agile methods require effective and efficient communication among stakeholders (i.e. users and customers) to achieve the highest project quality and customer satisfaction [19]. This paper refers to communication efficiency and communication effectiveness as "active communication" [32], [33]. Accordingly, communication efficiency is defined as delivering a message to a receiver with high quality and with minimal time, cost, effort, and resources required to establish communication [17], [33], [34]. Communication effectiveness is also defined as delivering a message to the receiver who understands it as it was intended with minimal disruption and misunderstanding, even if it takes a long time [17], [35]. Indeed, agile development is a communication-oriented approach that promotes efficient and effective communication between all stakeholders [36]. Yet, this paper empirically investigates how communication efficiency and communication effectiveness are related, which has not been discussed in the published literature. Although, it has been mentioned that the active communication is important for GDAD performance, however, rigorous empirical investigation is still required to understand how each dimension affects GDAD performance (RQ3). The findings of this paper show a significant impact of communication efficiency on communication effectiveness, on-time completion, on-budget completion, and quality; however, it is not significant on functionality. Moreover, the findings show a significant impact of communication effectiveness on functionality, quality, and

on-budget completion; however, not significant on-time completion.

This paper is structured as follows: the related literature review is presented in Section II. The research model and related hypotheses are discussed in Section III. The research method is discussed in Section IV. The findings are discussed in Section V. Section VI discusses the research implications and limitations. Finally, conclusions are presented in Section VII.

II. LITERATURE REVIEW

This section discusses the available literature about the central constructs of the research model (i.e. AEA, communication efficiency, communication effectiveness). It also discusses GDAD performance aspects (i.e. on-time completion, on-budget completion, software functionality, and software quality).

A. GDAD ACTIVE COMMUNICATION: EFFICIENCY AND EFFECTIVENESS

The definition of communication is quite different between communication scholars and agile development business [37]. Communication definitions (e.g., [38], [39]), in general, draw our attention to the importance of sharing information (i.e. communication effectiveness). For example, Kornstadt and Sauer [31] defines communication as the process in which participants create and share information with one another in order to reach a mutual understanding. However, since agile methods promise faster development, communication efficiency should be improved [19]. Thus, communication should be efficient and effective among stakeholders in agile development to achieve higher agility and customer satisfaction [17], [19], [40].

Agility, the core of agile development, identifies how the agile team should communicate and respond to the requirement's changes. Lee and Xia [28] [p.90] defined software development agility "as the software team's capability to efficiently and effectively respond to and incorporate user requirement changes during the project life cycle." Qumer and Henderson-Sellers [41] [p.289] define agility as "a persistent behavior or ability of a sensitive entity that exhibits flexibility to accommodate expected or unexpected changes rapidly, follows the shortest time span, uses economical, simple and quality instruments in a dynamic environment and applies updated prior knowledge and experience to learn from the internal and external environment." Conboy [42] defined agility as a continued readiness "to rapidly or inherently create change, proactively or reactively embrace change, and learn from change while contributing to perceived customer value (economy, quality, and simplicity), through its collective components and relationships with its environment" [p.340]. It is clear from the above agility definitions that agile team members need to communicate efficiently and effectively.

There are a number of definitions and descriptions of active communication [34]. Active communication is generally defined in terms of the sharing and understanding of information (e.g., [8], [19], [43]). Active communication is at the heart of agile development principles and practices. Agile development approaches encourage informal active communication using minimum documentation (e.g., the agile requirements backlog, plans, and card walls) [18], [44]. Moreover, active communication is composed of two important elements that correspond to our conceptualization of the two dimensions of GDAD active communication: communication effectiveness and communication efficiency [34].

Communication efficiency refers to sharing information and knowledge in a timely manner between distributed teams or distributed team members [16], [18]. The concept of communication efficiency was reformulated by Clark and Brennan [16] as a matter of minimizing communication costs and efforts [45]. Active communication refers to communication efficiency in terms of embracing various communication with high speed and low cost, effort and resources [19], [34], [43], [46], [47]. Communication effectiveness refers to the achievement of the intended purpose of the communication in a best possible manner [35], [48]. Thus, active communication needs to be effective so that it is fit for the purpose and be understood by the intended audience [8], [11], [19], [35], [49]. Communication effectiveness facilitates knowledge sharing between team members, which allows them to understand the requirements from clients and perform relevant development activities [50]. Active communication, in a co-located agile team, is achieved by changing to informal communication among team's member following agile practices such as planning games, project reviews, stand-up meetings, pair programming, small releases, Sprint planning, and continuous integration [19], [34]. This will facilitate knowledge transfer rapidly between team members, allows team members to understand the requirements from clients, and helps team members perform development activities efficiently [50].

However, in GDAD the chance of informal and direct communication (i.e. face-to-face) among distributed teams is very low. In the GDAD environment, the work is split across distributed sites which slows the work down [13], [47]. Therefore, there is a need for other techniques to enhance active communication. According to Sarker and Sarker [12], agility in GDAD is all about how efficiently and effectively teams communicate and respond to changes. Accordingly, some techniques and practices were proposed to enhance GDAD active communication such as providing structure by a coordinator [11], encouraging developers to work closely with project management teams on a daily basis, assigning an individual to play the role of the customer upfront, and using the available synchronous communication tools [51], following Scrum practices that enable higher communication effectiveness in GDAD as they provide a framework for communication that reminds team members to interact closely and regularly [21], increasing project monitoring and control between remote team members lead to better communication effectiveness in GDAD [27], and following

system metaphor that can serve as a communication platform with a common vocabulary that is stated to improve mutual understanding [52]. Moreover, AEA has been proposed as an important enabler for active communication in GDAD environment [23], [31], [53]. AEA can provide a common framework with a minimum level of control and documentation which enhances GDAD communication [11]. However, the empirical research about the role of AEA in GDAD communication is scarce. Hence, this paper will empirically investigate this role.

B. AGILE ENTERPRISE ARCHITECTURE

Traditional EA provides a long-term view of an organization's processes, technologies, and systems, which enables individual projects to build capabilities rather than just fulfill immediate needs [54]. EA is defined as "the organizing logic for business processes and IT infrastructure, reflecting the integration and standardization requirements of the company's operating model" [55] [P.9]. Other authors see EA as "the definition and representation of a high-level view of an enterprise's business processes and IT systems, their interrelationships, and the extent to which these processes and systems are shared by different parts of the enterprise" [56] [p.147]. Another way of looking at EA is as a means to inform, guide, direct, and constrain the decisions taken by human beings within organizations [57]. Unlike the traditional process and documentation-focused EA, AEA offers an incremental and people-focused approach which is aimed at enhancing agility [55], [58]. Enterprise is said to be agile when it is "responsive (scans, senses and reacts appropriately to expected and unexpected changes), flexible (adapts to expected or unexpected change at any time), speedy (accommodates expected or unexpected changes rapidly), lean (focuses on reducing waste and cost without compromising on quality), and learning (focuses on enterprise fitness, improvement and innovation)" [59] [p.3]. AEA refers to the process of adhering to agile development principles while translating business vision and strategy into effective enterprise change by flexibly creating, communicating and improving key requirements, principles, and models [60]. AEA should respond to changes effectively and efficiently rather than using available architectures to fine-tune understanding of the system(s) to handle potential changes [25], [56], [59]. Therefore, AEA should be easily, rapidly, and continuously communicated [61]. In this paper, AEA refers to "a blueprint that describes the overall structural, behavioral, social, technological, and facility elements of an enterprise's operating environment that share common goals and principles with the ability of responsiveness, flexibility, speediness, leanness, and learning" [59] [p.2].

Insufficient use of EA in GDAD is reported as a reason that hinders scaling agile development [62]. Since agile development prefers the minimum level of documentation, AEA should be documented to a sufficient level (as appropriate to situational needs) that can be understood by team members [53], [63]. Agility balances structure and flexibility,

so some structure, adequate documentation, and some up-front architecture help GDAD [63]. Batra [11] argued that large GDAD projects will need some degree of hierarchical structure to ensure accountability. AEA is seen as a tool to enhance GDAD performance [59], [64] and should evolve during software development iterations [65].

Moreover, AEA model can be used as a communication tool in GDAD which decreases the communication efforts and cost [66], increases knowledge sharing [67], and provides better understanding [68] since it provides a common language that is understood by GDAD teams and members [31], [69]. Using the architectural description helps the new team members to be successfully integrated into the team [70]. AEA helps in receiving early feedback to address any change needed and maintain early decisions and clear focus of the agile team [71]. Without AEA, road mapping, product management, and integration are done through many meetings that require traveling to headquarters locations or attending teleconferences outside work hours, in most cases [66], [72]. Avritzer *et al.* [73] developed a "system of systems" process to solve project management problems that arise in the coordination of global software development projects. The authors found that EA enhances communication among distributed teams, EA has the potential to guide task assignments and team coordination, EA encourages and ensures that developers can identify the design rules and assigned tasks, social architecture can be used to track the long-term project's communication, and EA is more helpful to less experienced developers.

C. GDAD PERFORMANCE

In general, both agile development literature and traditional software development literature have looked at project development performance through three dimensions: Quality, on-time completion, and on-budget completion [28], [74]. Functionality and quality were used interoperable in the literature. While some authors claim that functionality is part of quality (e.g., [75]) and define functionality as a part of a good working project that involves user's interaction with the product. Other authors claim that functionality is different from quality since it focuses on meeting requirements of certain product (i.e. focuses on the product itself) [76]. Nevertheless, functionality is an overlooked variable in GDAD performance research. Therefore, we argue that functionality is an important dimension of GDAD performance [7], [76], [77] that should be studied independently from quality, which may provide a more comprehensive understanding of GDAD performance. Therefore, this paper refers to four dimensions of GDAD performance: on-time completion, on-budget completion, functionality, and quality. On-time completion is defined as the extent to which a GDAD project meets its estimated duration [28], [74]. On-budget completion is defined as the extent to which a GDAD project meets its estimated cost [28], [74]. Functionality is defined as the extent to which the delivered GDAD project meets its pre-defined functional scope goals and technical and user requirements [28], [74].
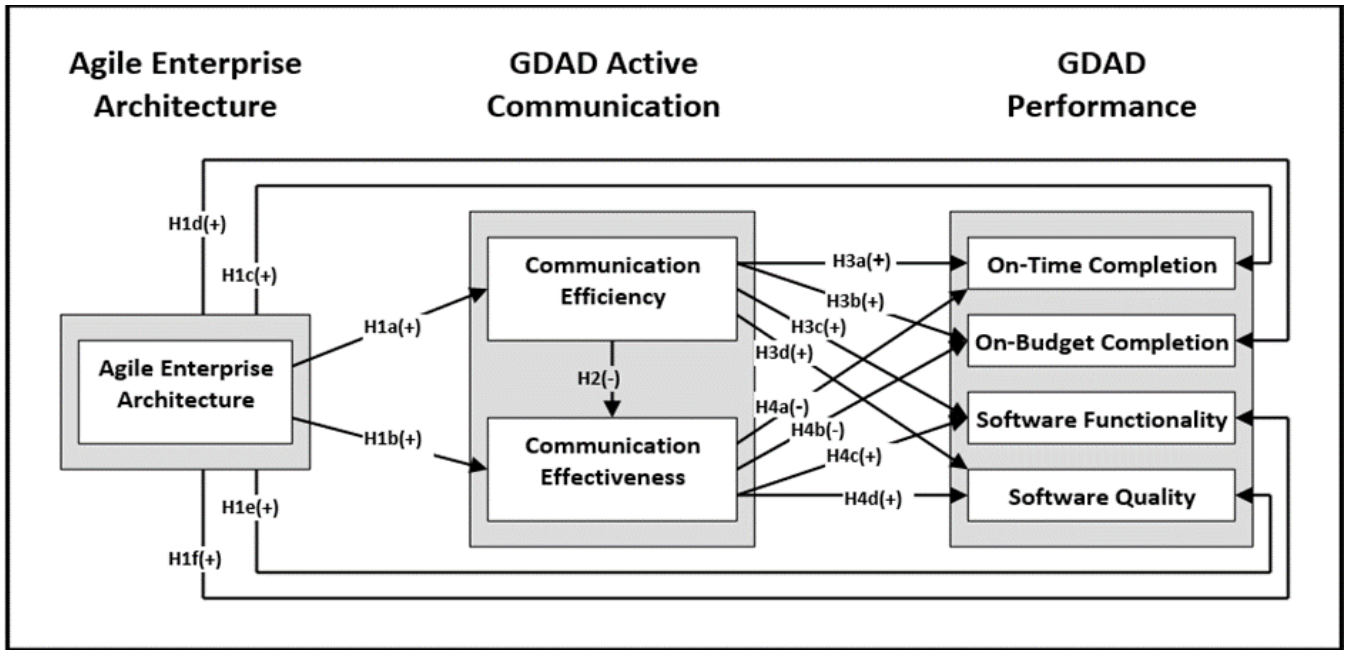
FIGURE 1. Research model [2].

Quality is defined as delivering GDAD project that solves a predefined problem and enhances the way its users doing their activities [78].

III. RESEARCH MODEL AND HYPOTHESES

Since communication is the heart of GDAD, this paper aims to study how GDAD communication can be enhanced by implementing AEA (RQ1). In addition, this paper aims to study if implementing AEA can enhance GDAD performance directly or is mediated by GDAD communication (RQ2). Moreover, this paper aims to study if GDAD performance is communication-oriented and how GDAD communication affects GDAD performance (RQ3). To answer these questions, we test hypotheses between the three constructs (AEA, GDAD communication, and GDAD performance) by analyzing data collected using the survey technique. The research model and related hypotheses are shown in Figure 1. The research model and hypotheses are discussed in greater detail in Alzoubi and Gill [2]. This model was built based on an extensive literature review. Hypothesis 1 suggests that AEA has positive impacts on both GDAD active communication and performance. Hypothesis 2 suggests that the relationship between GDAD communication effectiveness and efficiency is a trade-off relationship. Finally, hypotheses 3 and 4 suggest that GDAD communication effectiveness and efficiency impact differently on the GDAD performance aspects (on-time completion, on-budget completion, software functionality, and software quality).

Although there is no single theory that can address the research problem in hand and the above research model, the logic for this model (i.e. the relation between AEA

and active communication) is influenced by communication grounding [16]. Grounding (common ground) is defined as the process of creating mutual, common or joint knowledge, beliefs, and suppositions between two people. Clark and Brennan [16] state that "communication is a collective activity. It requires the coordinated action of all the participants. Grounding is crucial for keeping that coordination on track" [p.233]. When communication grounding is high and accurate, it facilitates the delivery of a clear message and more likely to be understood as intended [79], [80].

The purpose of grounding the communication was to decrease the frequency of communication [25], [27] and enhance active communication in GDAD environment [9], [19], at the same time, which results in higher GDAD performance [8]. This can be achieved by using tools and techniques that increase the shared knowledge (e.g., using patterns, practices, and tools) about joint or dependent activities (such as GDAD projects) among team members [16], [81]. To do so, this paper employs the AEA model as a means of communication grounding among GDAD teams.

A. RELATIONSHIP BETWEEN AEA AND GDAD ACTIVE COMMUNICATION

Agile principles explain that the best architectures and designs emerge from self-organizing teams, and emphasize that business people and agile developers must work together daily throughout the project [1]. These two principles work well for a small co-located agile team where team members and business people work out the best project architecture and design through active communication and

continuous collaboration [61]. However, in GDAD environment, these two principles would be hard to achieve [3], [25]. In such a complex GDAD environment, requirements and project architectures changes should be communicated among distributed GDAD teams in an efficient and effective manner [23], [61]. This could be attained by using the overall AEA (common repository) holistic integrated shared view [56], [63], [65], [82] along with using the available communication tools [69]. It has been suggested that the holistic and integrated views of AEA provide the "possibility to see and discuss how different parts (the ICT systems, the processes, etc.) are interconnected and interplay. Understanding means not only knowing what elements the enterprise consists of and how they are related from different aspects but also how the elements work together in the enterprise as a whole" [83], [83, p. 219]. AEA can provide a holistic and shared set of architectural views (e.g. business and technology views) to GDAD teams as the different parts of the different projects solution architectures (involving subsets of the overall AEA views) are developed and delivered by the GDAD teams in different increments at different times [55], [56]. Bass *et al.* [84] state that "architecture represents a common abstraction of a system that most, if not all, of the system's stakeholders, can use as a basis for creating mutual understanding, negotiating, forming consensus, and communicating with each other" [p.29].

In the GDAD environment, teams face a lack of active communication and generally experience more challenges in maintaining active communication needed for the progress of their tasks, the artifacts, and their respective offshore team members [85], [86]. In addition, in GDAD, teams have diverse cultural backgrounds and different spoken languages, which hinder active communication [86]. Consequently, different assumptions, priorities, and sufficient common knowledge using AEA are necessary to carry out the joint communication and collaborative activity [80], [87]. Using AEA allows all GDAD teams to ensure that they have achieved common knowledge [45]. Hence, actions (e.g., tasks) are aligned not because communicating members are mandated to take aligned actions, but because they share sufficient knowledge that helps them to adjust their actions in a manner appropriate for the other teams or members, which enables and enhances active communication [17], [79], [88]. In this sense, the need for formal communication should decline as AEA can, at least, partly substitute the need for formal communication and coordination by resolving other kinds of communication and coordination problems [88]. Therefore, this shared and integrated AEA view will reduce uncertainty just as frequent communication does [56], [88], produce positive attributions when real data are absent [89], increase enterprise awareness that will increase coordination among GDAD teams [89], and facilitate information sharing by providing common data definitions and structures [82].

In situations "where individuals have shared mental models, encoding and decoding familiar information should be faster" [48] [p.583]. So, high communication grounding

using the AEA shared view, on one hand, is associated with a reduced cognitive effort to encode and decode messages, yielding faster message transmission, so a message can be assessed and modified quickly [35]. It can also provide team members with the ability to receive immediate feedback [16]. On the other hand, low communication grounding may impair the development of understanding because members will not have the time required to fully process the information, which may cause a greater cognitive load on the individual [90] and encourage premature action [48]. Therefore, we propose

H1a: AEA positively affects the efficiency of GDAD communication.

AEA shared view may serve as a common information model for enabling rich communication among GDAD teams and can provide a single view of the AEA information to GDAD stakeholders [23], [61], [91], [92]. It also provides terms and concepts that serve as a common language for all GDAD teams, which enables clear communication [31], [53]. It decreases the misunderstanding or an unnecessary flow of communication due to the insufficient definition of a system and software structure [68]. It helps GDAD teams to coordinate their work through interfaces of their components such that each component can be developed separately, which means that the frequencies of communication as well as considering the development of other components is decreased [56], [89], and the need for synchronous communication is reduced [48]. To sum up, this shared view that provides simplicity as well as ease of development and incorporation of external developers, can be a mechanism for communication and coordination in GDAD and provide the same efficiencies as co-located development [66], [67]. Therefore, we propose

H1b: AEA positively affects the effectiveness of GDAD communication.

B. RELATIONSHIP BETWEEN AEA AND GDAD PERFORMANCE

AEA includes business and technology architectures views (e.g. infrastructure, platform, application) [91], which provide a holistic model of an IT-enabled business environment [55], [92]. AEA may help reducing or avoiding unnecessary support and IT costs, reducing resource duplication by involving optimal people in a process, and reducing skill variation and focusing on core competencies through selective outsourcing [56], [93]. It could improve resource integration and interoperability by improving performance, re-using of technology and expertise, and increasing IT responsiveness [55], [89]. Moreover, AEA can be considered as a placeholder for software quality, modifiability, security, and reliability [31], [92]. Therefore, we propose

H1c: AEA positively influences on-time completion of the GDAD project.

H1d: AEA positively influences on-budget completion of the GDAD project.

H1e: AEA positively influences GDAD project quality.

H1f: AEA positively influences GDAD project functionality.

C. RELATIONSHIP BETWEEN COMMUNICATION EFFECTIVENESS AND COMMUNICATION EFFICIENCY

''The context in which communication occurs can have a significant effect on the need for particular types of communication processes'' [48] [p.589]. The shared message may not be received as it was intended due to communication challenges in the GDAD environment [86]. The higher communication effectiveness comes at the price of a considerably longer time of communication [77], [79]. GDAD team tends to first decide what and how much they would communicate based on effort, time, and cost of communication. This choice, in turn, affects communication effectiveness. The short message may be insufficient to deliver clear information [16]. Low communication efficiency can negatively impact communication effectiveness by increasing delays that impede the rapid development of shared understanding [48], [80].

Moreover, if the message is complex, with large amounts of information or a high diversity of information, a team member will require more time to assess and deliberate on the information [48], [90]. Communication efficiency may impair the development of understanding because members will not have the time required to fully process the information, which may cause a greater cognitive load on the individual [48], [90] and encourage premature action [48]. Accordingly, increasing communication efficiency may come at the expense of communication effectiveness and vice versa. Therefore, we propose

H2: GDAD communication efficiency negatively affects the effectiveness of GDAD communication.

D. RELATIONSHIP BETWEEN GDAD ACTIVE COMMUNICATION AND GDAD PERFORMANCE

Sarker and Sarker [12] reported that being fast (e.g., fast delivery, fast communication) is the whole idea behind agility. Efficient communication results in high agile development performance by fast responding to customer requirements [64], [94]. Inefficient communication (i.e. longer development duration and extra cost) leads to delay in identifying requirements, changes, and project impacts which decrease the agile development performance [43], [46], [85]. In other words, high communication efficiency results in fewer amounts of extra time and costs required for handling ongoing requirements and changes which helps in meeting the assigned time and budget targets [64], [95]. Furthermore, optimizing and perfection of the teamwork increase as the GDAD team repeatedly and efficiently responds to similar types of requirement changes. Therefore, user requirements are satisfied by increasing GDAD communication efficiency which increases the software functionality and quality). Therefore, we propose

H3a. Communication efficiency positively influences the on-time completion of the GDAD project.

H3b. Communication efficiency positively influences the on-budget completion of the GDAD project.

H3c. Communication efficiency positively influences GDAD project functionality.

H3d. Communication efficiency positively influences GDAD project quality.

To understand customer's requirements and feedback, communication between GDAD teams and customers should be effective [21], [85], [96]. On the one hand, to achieve higher communication effectiveness, GDAD may need to spend considerably longer time and higher cost [85], [93], [96]. Moreover, shorter and faster communication may lead to noticeably lower communication effectiveness [77], [96]. In addition, the GDAD team may need new resources and capabilities or reconfigure existing resources and capabilities in order to effectively communicate customer's requirements and changes [28], [85]. This may result in adding a considerable amount of time and cost to deliver the project in GDAD [21], [28]. On the other hand, effective communication is crucial to understand the customer's requirements, to address the changes, to facilitate knowledge sharing, and to improve system design and correct configuration [19], [50]. This means that effective communication leads to higher software quality and functionality [9], [97]. Ineffective communication ''during any of the phases of system development is negatively correlated with system success'' [96], [p.283]. Therefore, we propose

H4a. Communication effectiveness negatively influences the on-time completion of the GDAD project.

H4b. Communication effectiveness negatively influences the on-budget completion of the GDAD project.

H4c. Communication effectiveness positively influences GDAD project functionality.

H4d. Communication effectiveness positively influences GDAD project quality.

IV. RESEARCH METHOD

A. RESEARCH PROCESS

In this paper, we used a quantitative method to investigate the relationships among the research model constructs shown in Figure1. We have developed a survey questionnaire. The survey method is recommended for investigating the relationships between a range of constructs, variables, or factors across a large population and is recommended for verification and validation purposes [98]. Moreover, the survey method helps to get information that cannot be achieved using observational techniques, and it aims to generalize the findings to the whole population of the study [98]. The questionnaire starts with an introduction that has the definitions of the constructs of the research model and explanation of the AEA driven GDAD approach (i.e. members that are part of or work for agile teams that implement AEA in their development process). The first section collected the demographic information about the respondents such as industry of respondents organization, the job title of the respondents, number of experience years in GDAD, number of teams include in GDAD projects, and number of team members. The questionnaire includes three main sections; AEA, GDAD active communication,

and GDAD performance. We used a seven-point Likert scale (i.e. 1 = strongly disagree; 2 = disagree, 3 = partially disagree, 4 = neutral, 5 = partially agree, 6 = agree, and 7 = strongly agree). We used close-ended questions in the questionnaire. We included the "neutral" option in the scale which may decrease the bias in data collected since respondents are not biased or forced to choose a negative or positive answer [99].

Content validity and face validity were carried out in order to ensure the survey questionnaire's reliability and accuracy [100]. In the content validity, the questionnaire was sent to five experts who assessed the questionnaire items for completeness, readability, and accuracy purposes. This was important in order to reach the agreement on which items to be kept in the questionnaire [101]. Three experts were GDAD practitioners (i.e. an architect, a developer, and a Scrum Master) and two experts were academics (i.e. assistant professors teaching agile development subjects) who had experience as agile developers. In the face validity, the questionnaire was sent to three Ph.D. students to complete and critique the questionnaire. This was important for questionnaire design, such as format, content, understandability, terminology, and ease and speed of completion [101]. The comments provided by the experts and Ph.D. students improved the content validity and face validity of the questionnaire.

A pilot study was conducted using the snowball sampling technique to validate and refine the survey questionnaire [102]. The survey questionnaire was sent to five respondents based on the pre-established unit of analysis (an individual who works in EA driven GDAD environment). Three of those respondents were contacts to one of the researchers who nominated another two respondents. The respondents were asked to complete the questionnaire and provide comments and suggestions about the difficulties in completing the questionnaire, suggestions to improve the questionnaire, and if there is a need to include additional item statements or delete items. Based on the answers and comments of participants, the questionnaire was further revised and changes were applied. The questionnaire's sample is provided in Appendix A.

B. STUDY SAMPLE

The survey respondents were team members of AEA driven GDAD teams. We did not target a specific role within the GDAD team (i.e. any agilest role such as developer, agile coach, team leader, Scrum master, analyst, architect, project manager, product owner, technical manager, and so on). The survey was conducted between May 2015 and October 2015. Since the focus of the paper was in gathering the experiences of a large number of agile team members in the GDAD environment, we sent the survey questionnaire to potential respondents in various industrial sectors (e.g., finance, telecommunications, and healthcare). According to Cohen's power analysis (see section V-A), the targeted sample was to get more than 84 complete surveys. Hence, we sent the survey link to 500 potential respondents.

We use the snowball sampling technique [102] to identify the potential respondents (450 respondents) form professional websites (e.g., LinkedIn and ResearchGate). Also, 50 respondents of the researchers' contacts inside Australia were contacted. The snowball sampling technique was used because it was difficult to identify the study sample [102]. Then, we sent the survey link to the potential respondents through emails. The questionnaire was collected through a web-based (i.e. SurveyMonkey) tool. The web-based questionnaire was preferred over other techniques like telephone and in-house survey since web-based allows the respondents to complete the survey any time they prefer and enables them to answer the questions more thoughtfully by taking their own time. To avoid privacy issues, we did not include questions like the respondent's name, organization name, organization location, etc.

A total of 260 surveys were returned, achieving 52 % survey response rate. After running data cleaning, screening, and missing data analysis, 100 surveys were exempted from the analysis. The exempted surveys were incomplete cases that had a percentage of missing data greater than 10 percent or had the missing data about the dependent variables [103]. Thus, 160 of the returned surveys were usable responses.

C. MEASURES

Appendix A provides the items for measuring the research model constructs. We developed new 7 measures for the AEA construct [100], as there are no existing measures in the literature. AEA was measured by how much EA is used in GDAD in aligning the project with business strategy and investment, involved in solution architecture, and used and shared among distributed teams. Communication efficiency was measured by five items [18], [104]. These items measure the extent to which the information communication among GDAD teams is shared quickly, easily, and with minimum cost. Communication effectiveness was measured by four items [18], [104]. These items measure the extent to which the shared information among GDAD teams is clear, detailed, and accurate.

On-time completion and on-budget completion were measured by two items [22], [28], [105]. These items measure the extent to which projects and tasks are completed on time and on budget, respectively. Software functionality was measured by three items [28]. These items measure the extent to which the GDAD project meets the functional and technical goals and customer requirements. Software quality was measured by three items [78]. These items measure the extent to which GDAD meets customer satisfaction and the capability to solve the customer problem.

V. FINDINGS
A. CHARACTERISTICS OF THE SURVEY SAMPLE

To assess the adequacy of our sample, Cohen's power was calculated [106] rather than applying the rule of thumb [107]

TABLE 1. The characteristics of the sample population.

Characteristic	Frequency	Percentage
Industry of the respondent organization		
Banking and financial	54	33.8
Telecommunications	32	20
Health care and medical	17	10.6
Automotive	15	9.4
IT support	15	9.4
Other	27	16.8
Job title of respondent		
Developer	22	13.8
Agile coach	25	15.6
Team leader/Scrum Master	44	27.5
Analyst	7	4.4
Architect	20	12.5
Project manager	17	10.6
Product owner	8	5
Technical manager	6	3.8
Other	11	6.8
GDAD experience of respondent		
Less than 2 years	16	10
2-4 years	62	38.8
5-10 years	64	40
10+ years	18	11.2
Number of teams in the project		
1 team	6	3.8
2 teams	24	15
3-5 teams	65	40.6
6-10 teams	40	25
11-15 teams	16	10
15+ teams	9	5.6
Number of members in the team		
1-3	5	3.1
4-10	41	25.6
11-20	38	23.8
21-30	27	16.9
31-50	20	12.5
51-100	9	5.6
100+	20	12.5

for Partial Least Squares (PLS) analysis. Since AEA was modeled as a formative construct, PLS analysis was used as it has the capability of analyzing both reflective and formative constructs. While the rule of thumb is valid for strong effect sizes, Cohen's formula has been proved to correctly predict power in most cases [108]. The sample size is well above 84 sample size according to Cohen's power analysis at the Alpha level of 0.05 and power level of 80. Most of the respondents worked for banking and finance organizations, most of the respondents (27.5%) were team leaders/Scrum Masters, most of the respondents (40%) had more than (5-10) years' experience in GDAD, most respondents (40.6%) answered that they usually worked with more than (3-5) teams in the same projects, and most teams (25.6%) included (4-10) members (see Table 1). In the ''industry of respondent organization'' category, 27 respondents (16.8%) were marked as other industries. Out of these 27 respondents, 4 respondents were from consultation industry, 4 from workforce management, 4 from mixed services, 3 from recruitment, 2 from education, 2 from governmental applications, 2 from mobile applications, 2 from payment solution, 2 from retail, and 2 from customer goods applications. Also, 11 respondents (6.8%) were marked as others in the ''job title of respondents'' category. Out of these 11 respondents, 3 respondents

were methodologists, 3 transform service, 3 QA/test, and 2 business stakeholders.

The nonresponse bias was examined following Sivo *et al.* [109] recommendation by splitting the sample into two groups (early group and late group). Then, the responses of the two groups were compared using demographics and other factors such as the number of teams, and the number of team members. The statistical test showed no significant difference between these two groups on these variables. This indicates that the nonresponse bias is not likely to be a serious concern. The common method bias issue [110] was also examined by conducting Harman's one-factor test statistical analysis [111]. The analysis revealed that there was no single factor that explained a substantial amount of variance (the most covariance explained by one factor is only 31 percent), which provides evidence that common method biases do not pose a significant threat to the measurement validity of this paper [107]. Moreover, the items that represent one construct were distributed and not grouped together [102] in the instrument to minimize the common method bias.

B. MEASUREMENT VALIDATION

The indicators of communication efficiency, communication effectiveness, on-time completion, on-budget completion,

TABLE 2. Constructs indicator; loading and cross loading; *p <.10, **p <.05, ***p <.01.

Scale Items	Efficiency	Effectiveness	On-Time	On-Budget	Functionality	Quality
EFFIC1	**0.883*****	0.423	0.631	0.440	0.495	0.458
EFFIC2	**0.883*****	0.393	0.594	0.516	0.489	0.496
EFFIC3	**0.931*****	0.474	0.594	0.473	0.456	0.506
EFFIC4	**0.907*****	0.416	0.578	0.464	0.381	0.444
EFFIC5	**0.815*****	0.506	0.598	0.510	0.385	0.415
EFFECT1	0.488	**0.897*****	0.367	0.438	0.601	0.562
EFFECT2	0.394	**0.890*****	0.351	0.498	0.621	0.635
EFFECT3	0.467	**0.908*****	0.333	0.381	0.547	0.660
EFFECT4	0.461	**0.922*****	0.399	0.430	0.574	0.546
TIME1	0.663	0.392	**0.977*****	0.799	0.407	0.405
TIME2	0.662	0.392	**0.977*****	0.804	0.433	0.417
BUDGT1	0.518	0.471	0.793	**0.975*****	0.494	0.489
BUDGT2	0.543	0.474	0.808	**0.976*****	0.469	0.427
FUNC1	0.483	0.599	0.415	0.472	**0.908*****	0.618
FUNC2	0.375	0.464	0.391	0.365	**0.785*****	0.525
FUNC3	0.418	0.592	0.295	0.420	**0.864*****	0.712
QLTY1	0.421	0.564	0.239	0.285	0.592	**0.825*****
QLTY2	0.416	0.567	0.460	0.508	0.654	**0.852*****
QLTY3	0.520	0.591	0.396	0.427	0.637	**0.913*****

software functionality, and software quality were modeled as reflective (i.e. caused by their latent constructs) indicators [112]. However, the indicators of AEA were modeled as formative indicators (i.e. these indicators are causes of and not caused by their latent construct) [112]. Reflective and formative constructs should be treated differently [112], [113]. This is because, unlike reflective constructs, formative constructs indicators are not expected to demonstrate internal consistency and correlations [112]. Moreover, SmartPLS 3.0 software [114] was used to validate the measurement model (both reflective and formative). The validation tests revealed that all reflective measures achieved a satisfactory level of construct validity and reliability. In addition, our validation tests revealed that no significant multicollinearity was found among the formative measures and satisfactory construct validity was achieved. Therefore, all of the measures were valid and reliable.

1) REFLECTIVE MEASUREMENT MODEL EVALUATION
According to Hair *et al.* [115], the reflective measurement model was estimated by calculating four values: (1) individual indicator reliability which refers to the degree to which the measurement item is free of random errors and yields consistent and stable measures over time [116], (2) internal

consistency reliability which was measured using Composite Reliability (CR), (3) convergent validity which refers to the extent to which a measure correlates positively with alternate measures of the same construct [116], and (4) discriminant validity which refers to the extent to which a construct is truly different from other constructs [116]. Firstly, the indicator reliability of reflective items was assessed using the outer loadings of each item on its respective latent construct. The outer loadings of the reflective indicators were above the recommended threshold of 0.708 and t-statistical above than 1.96 [117], as shown in Table 2 (where; EFFIC = communication efficiency, EFFECT = communication effectiveness, TIME = on-time completion, BUDGT = on-budget completion, FUNC = software functionality, QLTY = software quality), thus supporting item reliability.

Secondly, all reflective constructs achieved scores above the recommended value of 0.70 for CR as shown in Table 3. Thirdly, convergent validity was assessed using Average Variance Extracted (AVE). All AVEs values were above the required value of 0.50 [115]. Finally, discriminant validity was assessed using the indicators' cross-loadings and Fornell and Larcker [118] criterion. First, the indicators' cross-loadings reveal that no indicator loads higher on the opposing endogenous constructs (refer to Table 2).

TABLE 3. Composite reliability (CR), average variance extracted (AVE); formative construct (AEA) is not included.

Latent Construct	CR	AVE	Efficiency	Effectiveness	On-Time	On-Budget	Functionality	Quality
Efficiency	0.947	0.783	**0.885**					
Effectiveness	0.947	0.817	0.500	**0.904**				
On-Time	0.977	0.955	0.678	0.401	**0.977**			
On-Budget	0.976	0.952	0.544	0.484	0.821	**0.976**		
Functionality	0.889	0.729	0.501	0.649	0.430	0.493	**0.854**	
Quality	0.898	0.747	0.526	0.664	0.421	0.469	0.725	**0.864**

TABLE 4. The collinearity test, outer weights, outer loadings.

Formative Indicator	VIF	Outer Weights	Significance	Outer Loading	Significance
AEA1	2.261	0.308	**	0.815	***
AEA2	2.036	0.150	ns	0.690	***
AEA3	2.434	0.244	**	0.833	***
AEA4	2.402	0.002	ns	0.737	***
AEA5	2.406	0.267	*	0.775	***
AEA6	2.083	0.129	ns	0.536	***
AEA7	1.714	0.381	***	0.797	***

Second, in Fornell and Larcker criterion, the square root of each construct's AVE value should be greater than its highest correlation with any other construct. As shown in Table 3 (where; the numbers along the diagonal in bold font refer to the square root of AVE score; off-diagonal elements are correlations among latent constructs), the square root of AVE is greater than the variance shared by each construct and its opposing constructs, in all cases. Consequently, we achieved a high degree of discriminant validity of all constructs in this paper.

2) FORMATIVE MEASUREMENT MODEL EVALUATION
The reliability, convergent validity, and discriminant validity for the formative construct AEA were assessed using two methods: collinearity and indicator validity [117]. Firstly, collinearity which refers to the existence of high correlations between formative indicators [116] was assessed by Variance Inflation Factor (VIF). In Partial Least Squares Structural Equation Modeling (PLS-SEM), a VIF value of 3.3 or higher indicates a potential collinearity problem and the conflicting item should be removed as long as the overall content validity of the construct measures is not compromised [119]. All VIF values were found less than 3.3, as shown in Table 4.

Secondly, indicator validity was assessed by evaluating the significance and relevance of outer weights. Outer weight is the measure of the item's relative contribution to its assigned construct in the relationship from indicator to formative construct [115]. Complete Bootstrapping[1] procedure was

used to calculate the weight's significance and t values for each indicator. Bootstrapping is a resampling technique that draws a large number of subsamples from the original data (with replacement) and estimates models for each subsample, which is used to determine the significance level of the weight of indicators [115]. With seven uncorrelated indicators, the maximum possible outer weight is 0.378 ($1/\sqrt{7}$). Four indicator weights were significant as shown in Table 4. However, it was recommended that if the other outer weights are not significant, the researcher can further evaluate the outer loading magnitude value which should be >0.5 and significant [120]. As shown in Table 4, all indicators' outer loadings were significant and above 0.5. Eliminating formative indicators from the model should generally be the exception, as formative measurement theory requires that the measures fully capture the entire domain of a construct [113]. In other words, omitting an indicator is equivalent to omitting a part of the construct.

Moreover, the large number of indicators of the formative construct may cause such law weights of the indicators due to the competition between the indicators to explain the variance in formative construct [120]. The results suggested that AEA exhibited adequate convergent and discriminant validity.

C. TEST OF THE STRUCTURAL MODEL
The PLS algorithm and the bootstrapping procedure[2] was run to assess the significance of the relationships. The assessment of the structural model was conducted using the following criteria [115]: path coefficient, coefficient of

[1]The bootstrapping was run with the following settings: mean replacement, no sign changes option, 160 cases, and 5,000 samples
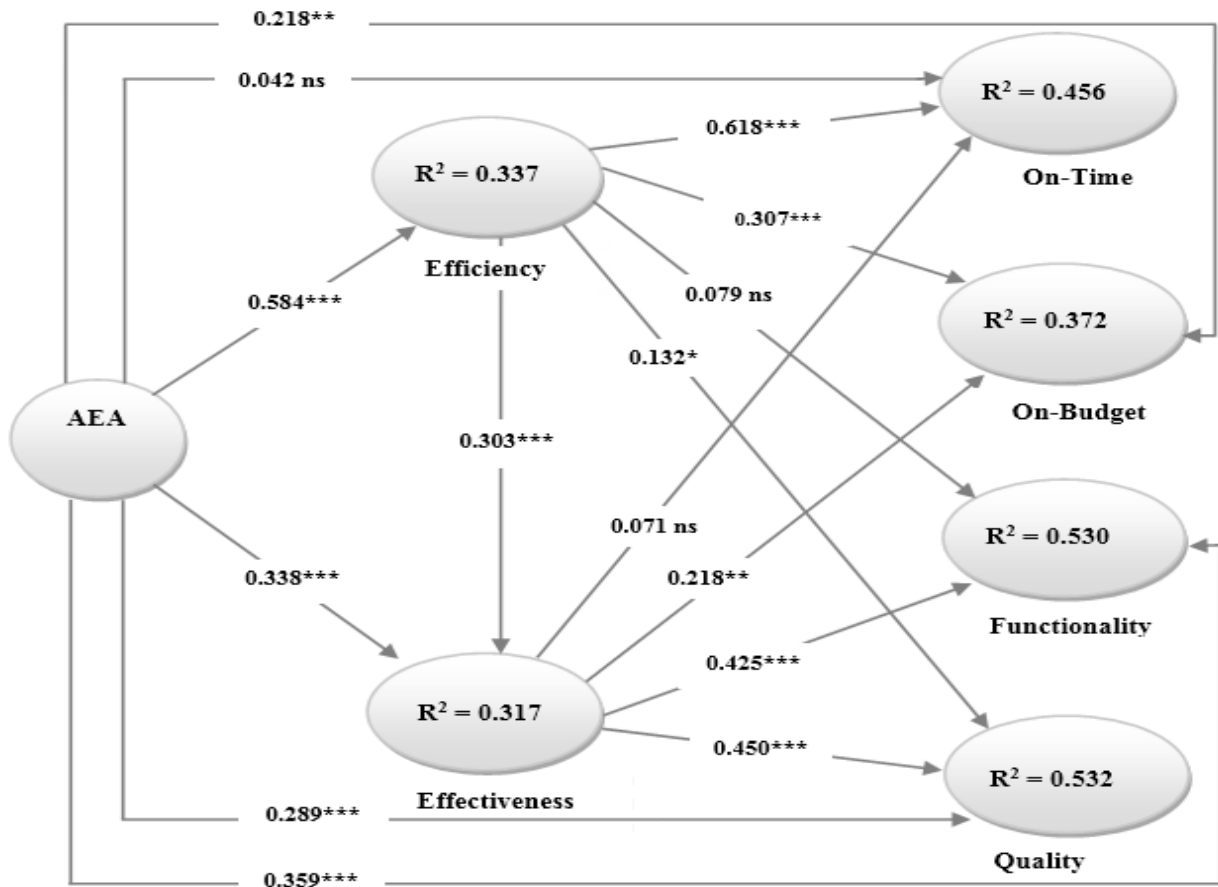
[2]Same settings of bootstrapping were used as in [1]

FIGURE 2. PLS results.

determination (R^2), effect size[3] for each path model (Cohen's f^2), and cross-validated redundancy (Q^2). Firstly, the path coefficients should be significant and consistent with proposed directions [115]. Figure 2 shows the path coefficients, the significance for each path, and R^2 values. Three hypotheses were found not supported: (1) the impact of AEA on "on-time" completion was found not significant, (2) the impact of communication efficiency on software functionality was found not significant, and (3) the impact of communication effectiveness on "on-time" completion was found not significant and positive, which is opposite to what it was hypothesized as a negative impact. Moreover, two hypotheses were found negatively supported (opposite to what it was hypothesized): (1) the relationship between communication efficiency and communication effectiveness was found significant but positive, and (2) the impact of communication effectiveness on "on-budget" completion was found significant but positive. To sum up, the results support Hypotheses 1a, 1b, 1d, 1e, 1f, 3a, 3b, 3d, 4c, and 4d but do not support Hypotheses 1c, 2, 3c, 4a, or 4b.

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[3]The effect size (f^2) is calculated according to the following equation: $f^2 = (R^2_{included} - R^2_{excluded})/(1 - R^2_{included})$. Where; $R^2_{included}$ and $R^2_{excluded}$ are the R^2 values of the endogenous latent variable when a selected exogenous latent variable is included or excluded from the model.

Secondly, R^2 is the central criterion for the evaluation of the inner model. R^2 refers to the model's predictive accuracy and represents the exogenous (independent) latent variable's combined effects on the endogenous latent variable [115]. An acceptable R^2 with 0.75, 0.50, 0.25, respectively, describing substantial, moderate, or weak levels of predictive accuracy [121]. AEA explains 33.7 percent of the variance in communication efficiency and 31.7 percent of the variance in communication effectiveness. AEA, communication efficiency, and communication effectiveness collectively explain 45.6 percent of the variance in "on-time" completion, 37.2 percent in "on-budget" completion, 53 percent in software functionality, and 53.2 percent in software quality.

Thirdly, f^2 values were obtained as shown in Table 5, which evaluates whether the omission of a specified exogenous construct has a substantive impact on the endogenous constructs [115]. f^2 values of 0.02, 0.15, and 0.35, represent small, medium, and large effects respectively of the exogenous latent variable [106]. A strong relationship was found between AEA and communication efficiency, and communication efficiency and "on-time" completion. Medium relationships were found between AEA and functionality, communication effectiveness and functionality, and

TABLE 5. Effective size f^2 of latent variables, predictive relevance of the model.

Endogenous latent variable	f^2 of AEA	f^2 of Efficiency	f^2 of Effectiveness	Q^2 values
Efficiency	0.517			0.257
Effectiveness	0.112	0.090		0.256
On-Time	0.002	0.433	0.006	0.435
On-Budget	0.046	0.098	0.052	0.362
Functionality	0.166	0.008	0.264	0.373
Quality	0.108	0.023	0.297	0.390

communication effectiveness and quality. All other relationships were found small.

Finally, the cross-validated redundancy measure (Q^2) [122], [123] is examined as a criterion of the predictive inner validity of the model. Q^2 can be computed using the blindfolding procedure in SmartPLS. Q^2 predicts the data points of indicators in reflective measurement models of endogenous constructs [121]. Q^2 value larger than zero indicates that the exogenous constructs have predictive relevance for the endogenous construct under consideration, whereas Q^2 value smaller than zero represents a lack of predictive relevance [124]. All Q^2 values were found to range significantly above zero, thus indicating the exogenous constructs' high predictive power. Table 5 summarizes the f^2 and Q^2 values.

Moreover, we tested a modified second-order PLS model to examine the effects of AEA, communication efficiency, and communication effectiveness on overall GDAD performance by combining all four performance measures. We found that all AEA, communication efficiency, and communication effectiveness have a significant positive effect on the overall development performance. Detailed results are reported in Appendix B. In addition, mediation roles of communication efficiency and communication effectiveness were tested, as discussed in Appendix C.

VI. DISCUSSION

Traditional EA has been criticized for being slow, inflexible and is often considered as a cost center [92]. An alternative agile or adaptive approach to EA has been proposed and claims to deal with the shortcomings of traditional EA [23]. This claim lacks empirical evidence support and marks the need to empirically analyze the impact of AEA on IS project development, in particular large-scale communication-focused GDAD. This paper empirically investigated the relationships between three constructs: AEA, GDAD active communication, and GDAD performance. The main focus of this paper was to study the impact of AEA on communication efficiency and communication effectiveness, which enhances the IS project performance, in turn. This was done using a quantitative approach through a survey. Similar to any other empirical research, this paper has some

limitations and implications, which are discussed in the following sections.

A. IMPLICATIONS FOR RESEARCH

This paper aims to answer three research questions; how AEA affects GDAD communication (RQ1), how AEA affects GDAD performance (RQ2), and how GDAD communication affects GDAD performance. The findings and insights of this paper have significant implications for research in GDAD. This paper provides useful insights into the positive impact of AEA on both communication efficiency and communication effectiveness and overall GDAD performance. This was necessary to empirically justify the need and value of AEA for GDAD.

Agile development approaches promote best architectures is an adaptive short-term plan that evolves during software development by a self-organizing team. However, the empirical evidence and theoretical foundation that have been provided to support this principle in GDAD are scarce. The findings revealed significant ($p < 0.01$) positive relationships between AEA and communication efficiency and communication effectiveness. Therefore, H1a and H1b were supported. The findings draw our attention to the conclusion that AEA can help to enhance communication among GDAD teams. Thus, the role of AEA can be seen as a communication enabler.

Moreover, this paper provides empirical evidence that AEA (e.g., solution architecture) is an important factor that can used to GDAD performance. The results show that AEA has positive significant effects on on-budget completion ($p < 0.05$), functionality ($p < 0.01$), and quality ($p < 0.01$). Therefore, H1c, H1d, and H1e were supported. However, the relationship between AEA and on-time completion is not significant and fully mediated by communication efficiency. Therefore, H1f was not supported. The reason for this insignificancy may relate to the thought that developing and understanding AEA elements need some time which may not preferable by most agile developers. Our findings provide empirical evidence that AEA as a whole is an important variable that GDAD organizations may apply (AEA driven GDAD) to enhance their communication and increase their GDAD performance.

The findings of this paper may benefit researchers intending to investigate the impact of AEA on other aspects of the GDAD such as legal compliance, team habits, and customer complaints. The researcher may also be interested in individual domains or views (e.g. business and technology) of AEA and their impact on GDAD communication and GDAD performance. The scope of this paper was to study AEA as a whole. This is because the individual GDAD project or solution architectures include a subset of different integrated business and technology views of the AEA. The study of individual views of EA was beyond the scope this paper is not practical.

This paper adds to the existing knowledge body by differentiating between two dimensions of communication:

communication efficiency and communication effectiveness. The results suggest a significant ($p < 0.01$) positive effect of communication efficiency on communication effectiveness, which is opposite to what it was hypothesized as a negative impact (H2). The reason for this positive relationship maybe because communication efficiency is likely to result in timely and rapid communication, which can increase the effectiveness of communication among GDAD teams. GDAD team in requiring or responding to customer changes may determine how efficiently (rapidly) to establish communication to solve or discuss the new changes. With this reasoning, communication still effective although it is efficient. However, a possible reverse direction of the relationship, that is, communication effectiveness affecting communication efficiency, should not be completely ruled out as the relationship is yet to be fully understood. GDAD team in requiring or responding to customer changes may determine the extent of communication needed to respond to changes. With this reasoning; however, communication effectiveness is expected to negatively affect communication efficiency, which is not consistent with this paper's results. Nevertheless, researchers need to distinguish between the two dimensions of active communication; communication efficiency and communication effectiveness, when studying and theorizing GDAD communication. Moreover, future research should examine the reverse causal relationship between communication efficiency and communication effectiveness.

The findings revealed significant ($p < 0.01$) positive relationships between communication efficiency and on-time and on-budget completion. Therefore, H3a and H3b were supported. Moreover, the relationship between communication efficiency and quality was found small but significant ($p < 0.1$), and thus, H3d was supported. However, the relationship between communication efficiency and functionality was found not significant and fully mediated by communication effectiveness, which is against our hypothesis. Therefore, H3c was not supported. The reason for this may be because GDAD functionality requires a clear understanding (i.e. through communication effectiveness) of customer requirements, which requires longer time of communication.

In addition, the findings revealed significant ($p < 0.01$) positive relationships between communication effectiveness and functionality and quality. Therefore, H4c and H4d were supported. Moreover, the relationship between communication effectiveness and on-budget completion was found significant ($p < 0.05$) but positive, which is opposite to what it was hypothesized as a negative impact. Therefore, H4b was not supported. However, the relationship between communication effectiveness and on-time completion was found not significant and positive, which is opposite to what it was hypothesized as a negative impact. Thus, H4a was not supported. The reason for the results of H4a and H4b maybe because in the GDAD project, usually, the distributed teams provide the expected time to finish and the cost at the beginning of the project, especially if the distributed teams are contractors.

The above results of the effects of communication efficiency and communication on the GDAD performance aspects draw our attention to the conclusion that GDAD performance is impacted differently according to the dimension of communication (i.e. communication efficiency or communication effectiveness), which is consistent with our conceptualization of active communication. These subtle yet significant relationships should not be overlooked, and future research may investigate their impacts on GDAD performance from other perspectives.

This paper represents a first step toward building theories that provide insights about the conceptualization of AEA and GDAD communication. This paper provides rich quantitative statistics of unexplored phenomena which could stimulate the development of new insights and theory [29]. The model and measures developed in this paper can help organizations improve understanding of GDAD communication related to AEA and GDAD performance. They also can provide the initial tools for assessing and managing the level and impact of GDAD communication. Since sound measurements can only be established through a series of replications and validations, future research should further validate and refine the measurement scales with comparative data. In particular, future research needs to further refine the AEA measure (new proposed and validated measures) in order to increase the internal consistency reliability of the construct. In particular, as shown in Table 4, the weight of AEA2 (''enterprise architecture documentations are regularly updated to align with the projects in GDAD''), AEA4 (''enterprise architecture is used to assess major project investment in GDAD''), AEA6 (''solution architecture evolves from small iterations, and the changes in solution architecture are reflected in enterprise architecture'') were lower than other AEA items. Therefore, documenting AEA, using AEA in assessing GDAD project investment, and the relationship between the solution architecture and AEA needs to be further investigated.

B. IMPLICATIONS FOR PRACTICE

While traditional EA is perceived as a hindrance by agile teams, this paper offers new insights by providing empirical evidence that GDAD communication can be enhanced by using AEA without burdening the agile teams and without unnecessarily increasing the number of visits between distributed sites or introducing additional communication tools or technology. Rather, it suggests that sharing integrated AEA views (e.g. business architecture view, technology architecture view) among GDAD teams will serve as a base or a common language that will increase the common understanding (communication grounding) about the holistic business and technology landscape of an enterprise and related requirements. These shared views of AEA will lead to more efficient and effective communication among teams working on different aspects or components of software projects in GDAD environment. This paper also provides empirical evidence that GDAD performance will be enhanced by implementing AEA. This paper highlights the value of using AEA, as

opposed to traditional EA that has been criticized for not delivering value, for delivering successful IS projects.

Furthermore, the GDAD communication literature tends to assume that communication is behind the high GDAD performance without paying enough attention to the two different dimensions of active communication neither recognizing their differential effects on different aspects of GDAD performance. Practitioners need to be aware of the complexity of GDAD active communication and understand the tension between its two different dimensions (i.e. efficiency and effectiveness) in order to build appropriate types of GDAD communication environment. For instance, when time and cost are top priorities, teams can be better off by selectively communicating (rather too much or unnecessary communication) and thus increasing communication efficiency. Communication channels such as instant messaging can be useful for improving response efficiency [125]. GDAD teams can maintain an appropriate balance between the two active communication dimensions by using synchronous and asynchronous communication channels (according to the extent of efficiency and effectiveness) and implementing such agile development practices as daily meetings and weekly meetings. Moreover, this indicates to practitioners that agile principles could be fine-tuned to deliver high-GDAD performance [25], [34].

C. LIMITATIONS

Like any other empirical study, there are some limitations of this paper that should be considered when interpreting its findings. It was not an easy task to identify and develop the measures for the complex concepts in hand such as AEA, GDAD communication and performance. A rigorous, multiphase approach was employed to develop the new measures of the AEA construct; however, the final measurement items may have some weaknesses. Although the identified concepts and measures reflect the most critical aspects of AEA from the practitioners' point of view, they may not cover the whole range of the theoretical domain of the construct. AEA items include alignment between business and technical views, updating EA, defining the project by EA, defining the role of solution architecture that reflects EA and guides projects, and the governing role of EA in the GDAD project. This list may not be exhaustive because there are other potentially important EA components such as social process and organizational structure. This is a typical nature of research and more concepts and measures can be identified to study other aspects of AEA in this continuous process of research and development. This paper fills a small gap of research and does not claim to address all aspects of such large and complex domains of EA and GDAD. Future research is needed to develop a more comprehensive measure of AEA.

Further, it is important to note that there are a number of definitions of EA and AEA. The survey respondents may have used their own experience-based thinking in interpreting or the misinterpreting measurements. This could be considered as a limitation of this paper, although we have not found

any statistical evidence of potential misinterpretation to the measurement. Future research is needed to further enhance and validate the measures and findings of this paper. These limitations and future research possibilities mark the need for more empirical studies in this important and complex area of integrated AEA and GDAD research and development.

Moreover, the data was collected by the end of 2015 which may represent another limitation of the findings of this paper. However, studying the impact of AEA on GDAD is still in its infant stage. Therefore, we can argue that the findings of this paper will be of great help to both researchers and GDAD organizations.

VII. CONCLUSION

In order to deal with the ever-increasing competition and optimization needs, software development organizations have adopted the GDAD approach. GDAD performance perceived to be largely dependent on active communication (i.e. communication efficiency and communication effectiveness) among teams, which are geographically distributed across different location and operate in different time zones and language. Active communication seems important for GDAD performance, however, limited theoretical and empirical evidence have been found in the published studies. Hence, this paper provides such theoretical and empirical insights into the relationship between the active communication dimensions and their impacts on GDAD performance aspects. In addition, as the active communication is the heart of agile development, this paper provides an innovative prescription to enhance active communication in GDAD environment by employing AEA. Moreover, this paper provides empirical evidence that AEA, communication efficiency, and communication effectiveness together increase the GDAD performance. Thus, this paper presents the first step in theorizing and empirically analyzing the relationships between AEA, active communication, and GDAD performance. Therefore, many issues and questions in this context are yet to be addressed in future research. The findings of this paper would set the foundation for developing and examining theories in the context of AEA driven GDAD. In addition, the findings would provide guidance to GDAD organizations to further investigate, prioritize and enhance active communication in order to improve their GDAD performance.

APPENDIX
A. MEASUREMENT SCALES AND ITEMS [100]

Since enterprise architecture, communication, and GDAD performance may go by different titles in different organizations, the respondent was asked to refer to the following definitions while completing this survey.

Agile Development: Software development that rapidly creates change, proactively or reactively embraces change, and learns from change while contributing to perceived customer value. Scrum and XP are two examples of agile methods.

GDAD: Agile development that includes a number of teams and/or team members distributed over different locations and time zones.

EA: A blueprint that describes the overall structural, behavioral, social, technological, and facility elements of an enterprise's operating environment that share common goals and principles. Enterprise architecture includes different architecture domains such as Application architecture, Platform architecture, Infrastructure architecture, Business architecture, Solution architecture, and Information architecture.

AEA: EA that applies agile principles and focuses on collaboratively and incrementally developing, adapting and sharing information about business and IT elements, their relationships to each other and the overall enterprise environment to effectively guiding the implementation of a number of projects.

Communication: Exchanging information or messages between two parties (i.e. sender and receiver). Good communication should be efficient and effective.

Communication Efficiency: Delivering high-quality messages with minimal time, cost, effort, and resources.

Communication Effectiveness: Delivering a message as it was intended with minimal disruption and misunderstanding, even if it takes a long time.

On-time completion refers to the extent to which a software project meets its baseline goals for the duration.

On-budget completion refers to the extent to which a software project meets its baseline goals for cost.

Functionality refers to the extent to which the delivered project meets its functional goals, user needs, and technical requirements.

Quality refers to how good the work is (according to ISO 8402, it is "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs").

AEA can be used as an integrated shared view in GDAD. Here, we refer to this approach as AEA driven GDAD approach, as shown in Figure 3.

This diagram explains how "AEA driven GDAD approach" can be used in GDAD environment.

As the diagram shows, we have different architectural views according to different architectural levels (enterprise project management levels).

1. Distributed teams (up to N teams) share the "project architecture view".
2. Different projects (up to N projects) share the "program architecture view". The same is applied to the "solution architecture view", which can have "N" number of program architectures.
3. Each architecture updates the architecture above. All architectures are then updated and shared using the enterprise architecture integrated knowledge base. This knowledge base can be represented in multiple repositories which grant access to all distributed stakeholders. This way ensures that all stakeholders are updated with the latest changes (i.e. project or program changes).
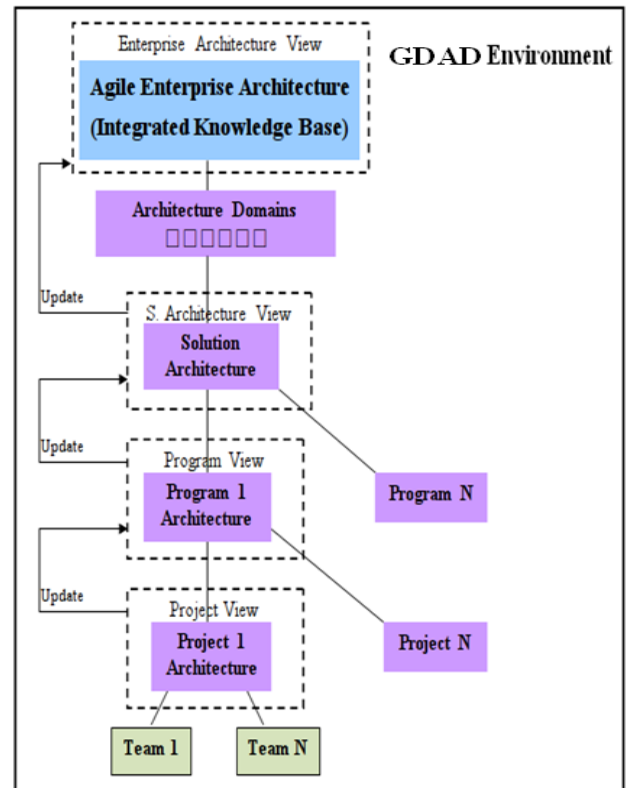

FIGURE 3. EA driven GDAD approach [126].

Using AEA driven GDAD approach, identify to what extent do you agree or disagree with the following statements.

AEA (formative) (1 = strongly disagree; 7 = strongly agree)

1. AEA framework and the framework of GDAD are aligned (AEA1)
2. AEA documentations are regularly updated to align with the projects in GDAD (AEA2)
3. AEA is used to define projects/programs (e.g., business/IT gap analysis) in GDAD (AEA3)
4. AEA is used to assess major project investment in GDAD (AEA4)
5. Solution architecture, as a part of enterprise architecture, guides the projects at program levels and project levels in GDAD (AEA5)
6. Solution architecture evolves from small iterations, and the changes in solution architecture are reflected in enterprise architecture (AEA6)
7. AEA is used to govern project implementation in GDAD (AEA7)

Communication efficiency (reflective) (1 = strongly disagree; 7 = strongly agree)

1. Information needed about GDAD project is achieved quickly (EFFIC1)
2. Information needed about GDAD project is achieved easily (EFFIC2)
3. The stakeholders needed to communicate with in GDAD are reached quickly (EFFIC3)
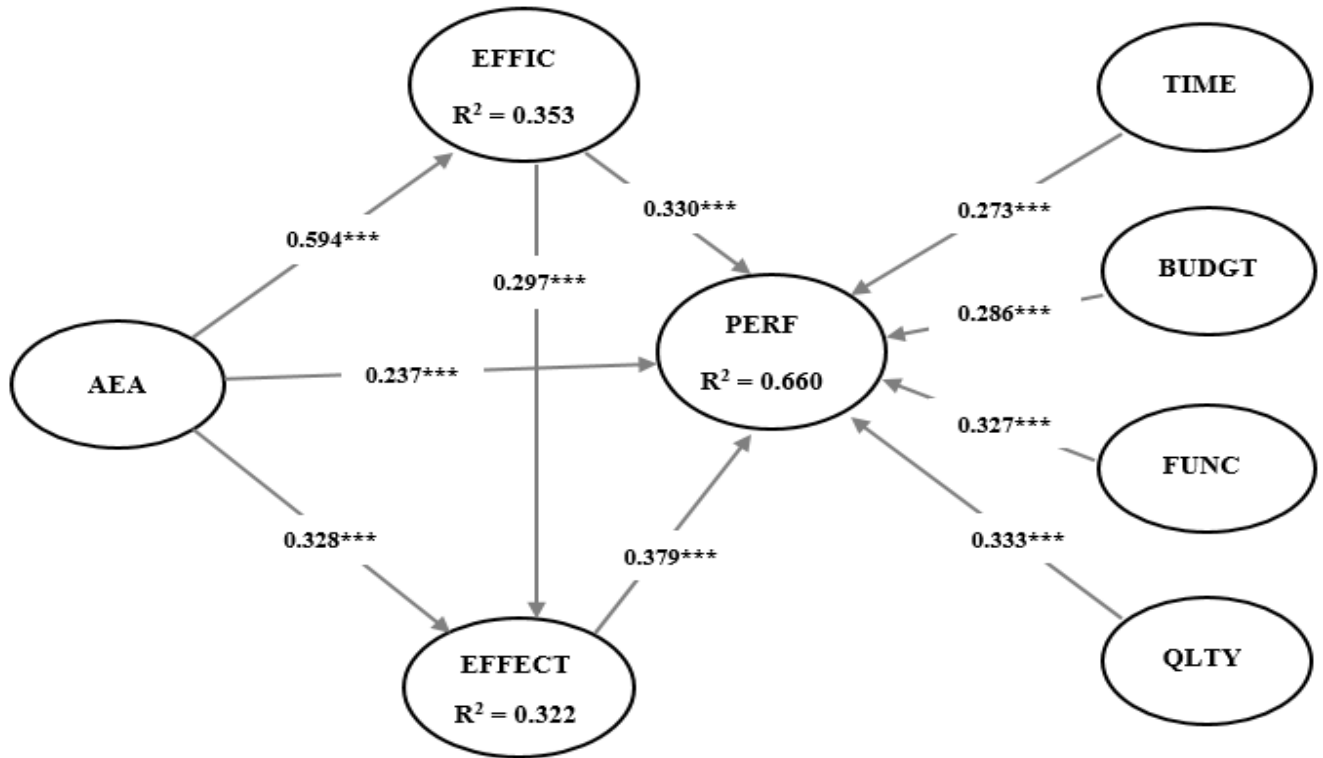
FIGURE 4. Results of the second-order PLS model.

4. The stakeholders needed to communicate with are reached easily (EFFIC4)
5. The cost of communication (e.g., less traveling to meet face-to-face) in GDAD is decreased (EFFIC5)

Communication effectiveness (reflective) (1 = strongly disagree; 7 = strongly agree)

1. All GDAD team members are clear about their tasks (EFFECT1)
2. Enough information is provided about customer requirements and project progress to GDAD team members (EFFECT2)
3. Detailed information is provided from distributed stakeholders (EFFECT3)
4. Accurate information is provided from distributed stakeholders (EFFECT4)

On-time completion (reflective) (1 = strongly disagree; 7 = strongly agree)

1. GDAD project is completed on-time according to the original schedule (TIME1)
2. GDAD teams complete their tasks on-time according to the original schedule (TIME2)

On-budget completion (reflective) (1 = strongly disagree; 7 = strongly agree)

1. GDAD project is completed on-budget according to the original budget (BUDGET1)
2. GDAD teams complete their tasks on-budget according to the original budget (BUDGET2)

Functionality (reflective) (1 = strongly disagree; 7 = strongly agree)

1. GDAD project achieves its functional goals (FUNC1)
2. GDAD project meets its technical functional requirements (FUNC2)
3. GDAD project meets customer's functional requirements (FUNC3)

Quality (reflective) (1 = strongly disagree; 7 = strongly agree)

1. GDAD project solves the given problem (QLTY1)
2. GDAD project improves the way of customers' use to perform their activities (QLTY2)
3. GDAD project achieves customer's satisfaction (QLTY3).

B. TEST OF A SECOND ORDER PLS MODEL

A modified second-order PLS model was tested to examine the effects of AEA, communication efficiency, and communication effectiveness on overall GDAD performance. This was conducted by combining all four performance measures. AEA, communication efficiency, and communication effectiveness were found to have a significant positive effect on the overall development performance.

We have modeled GDAD performance construct as a second-order latent variable using its four first-order constructs (i.e. on-time completion, on-budget completion, software functionality, software quality). Since PLS lacks the

TABLE 6. Total effect sizes of the mediation relationships.

	AEA*Efficiency			AEA*Effectiveness			Efficiency*Effectiveness		
	Effect	Sig.	Mediation Type	Effect	Sig.	Mediation Type	Effect	Sig.	Mediation Type
Effectiveness	0.041	ns	No mediation						
On-Time	0.151	**	Full mediation	-0.101	ns	No mediation	0.035	ns	No mediation
On-Budget	0.255	***	Partial mediation	-0.108	ns	No mediation	0.079	ns	No mediation
Functionality	0.021	ns	No mediation	0.055	ns	No mediation	0.129	***	Full mediation
Quality	0.107	ns	No mediation	0.143	*	Partial mediation	0.164	**	Partial mediation

capability to directly test second-order models, we applied the "two-stage approach" [127]. In the two-stage approach, the first-order constructs are tested, in the first stage. In the second stage, the first-order factor scores are used as indicators of the second-order construct.

All AEA (0.237, p < 0.01), communication efficiency (0.330, p < 0.01), and communication effectiveness (0.379, p <0.01) significantly and positively affect the second-order GDAD performance (PERF) construct, as shown in Figure 4. 66 percent of the GDAD performance variance is collectively explained by AEA, communication efficiency, and communication effectiveness. AEA explains 35.5 percent of the variance in communication efficiency. AEA and communication efficiency collectively explain 32.2 percent of the variance in communication effectiveness. The other paths' coefficients have not changed in the second-order model, which indicates that the research model is a robust model.

C. TEST FOR MEDIATION ROLE IN THE PLS MODEL
Mediation is the situation were a mediator variable to some extent absorbs the effect of an exogenous on an endogenous construct in the PLS path model [115]. As shown in Figure 1, communication efficiency and communication effectiveness may mediate the relationships between AEA and GDAD performance aspects, and communication effectiveness may mediate the relationships between communication efficiency and GDAD performance. Although Sobel test [128] has been widely used to test the mediation effect, it is not a noble approach since it does not always discover the mediation effect if the data are not conforming to Baron and Kenny's criteria for establishing mediation such that the unexplained direct path can indicate an omitted mediator [129]. Sobel test "relies on distributional assumptions, which usually do not hold for the indirect effect. The multiplication of two normally distributed coefficients results in a non-normal distribution of their product. Furthermore, the Sobel test requires unstandardized path coefficients as input for the test statistic and lacks statistical power, especially when applied to small sample sizes" [115], [p.223]. Therefore, it is recommended to follow Preacher and Hayes [130] and bootstrap the sampling distribution of the indirect effects, which works for simple and multiple mediator models [115], [129].

According to Zhao et al. [129], to test the mediation effect, we investigated the significance of the indirect effects (i.e. AEA* Efficiency, AEA*Effectiveness, and Efficiency*Effectiveness). By running the bootstrapping routine (5000 samples, 160 cases), the results of indirect effects are shown in Table 6. According to Zhao et al. [129], if the indirect effect is significant then we check for the direct effect. If the direct effect is significant, then we have complimentary (partial) mediation; however, if the direct effect is insignificant then we have indirect (full) mediation only. Accordingly, the relationship between AEA and on-time completion was fully mediated by communication efficiency since the indirect effect (AEA*Efficiency→On-Time) was significant and the direct effect (AEA→On-Time) was not significant. In addition, communication efficiency partially mediated the relationship between AEA and on-budget completion since the indirect effect (AEA*Efficiency→On-Budget) was significant and the direct effect (AEA→On-Budget) was significant. On the other hand, communication effectiveness partially mediated the relationship between AEA and quality. However, the relationship between AEA and functionality was not mediated by either communication efficiency nor communication effectiveness since the indirect effects (AEA*Efficiency→Functionality and AEA*Effectiveness→Functionality were not significant. Moreover, communication effectiveness was found to fully mediate the relationship between communication efficiency and functionality, and partially mediate the relationship between communication efficiency and quality.

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