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Exploring the Adoption of Big Data Analytics in the Oil and Gas Industry: A Case Study

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Abstract The oil and gas industry relies heavily on IT innovations to manage business processes, but the exponential generation of data has led to concerns about processing big data, generating valuable insights, and making timely decisions. Many companies have adopted Big Data Analytics (BDA) solutions to address these challenges. However, determining the adoption of BDA solutions requires a thorough understanding of the contextual factors influencing these decisions. This research explores these factors using a new Technology-Organisation-Environment (TOE) framework, presenting technological, organisational, and environmental factors. The study used a Delphi research method and seven heterogeneous panelists from an Oman oil and gas company. The paper provides theoretical and practical contributions to BDA research, adding three new factors to the TOE framework and building a conceptual framework that fits the industry context. The findings revealed twenty factors, with organisational strategy, business framework, and suitability being added to the TOE framework. Among all, data quality was identified as the most significant factor.

Keywords: *Big data analytics, Technology-organization-environment (TOE) framework, Delphi research method, Organizational strategy, Business framework*

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1. Introduction

In the last decade, big data analytics has been identified as a source of change management in various industries, which has enabled decision-making and innovations through the use of large data sets. This technology has brought change in the operation, customer relations and business development in various organizations worldwide, especially in the oil and gas industry. This industry has been a catalyst for the economic advancements of many countries around the world. It is considered one of the largest industries in the world, with facilities in several locations. The exploration, production, and operation processes in the oil and gas industry tend to be very huge, complex, and expensive. Hence, making decisions in any process should be assessed carefully to avoid potential tangible (i.e., financial, human resources, and assets) and intangible (i.e., reputation and

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employee morale) losses. Therefore, oil and gas companies always tend to rely on the available data when making critical decisions (Gidiagba et al., 2023; Karbassi Yazdi et al., 2022). The main challenge within the industry is the availability of too much data and not enough information (Li & Hu, 2022; Ochieng et al., 2018; Sumbal et al., 2019).

The oil exploration projects require making critical decisions, such as whether to explore or drill, based on the availability of subsurface data (La et al., 2020), which is generated by seismic data centers. However, modern seismic data centers may contain as much information as 20 petabytes, which is nearly equivalent to 926 times the size of the U.S. Library of Congress. It is assumed that if this data were printed into books and put on a continuous. It would probably go around approximately six times the Earth's equator (Durall et al., 2023; Perrons & Jensen, 2015). For this reason, the process of making data-driven decisions becomes very complicated and stressful.

Consequently, many oil and gas companies became attracted to adopting BDA solutions to help them gain valuable insights on time. However, some companies fail to capture value from BDA initiatives despite the potential benefits of these technologies (Corte-Real et al., 2017; Kaisler et al., 2013; Sarrakh et al., 2019). Thus, companies need to study all the contextual factors associated with the adoption of any BDA solution before making any investment decisions.

Previous research that looked at what makes an organization want to adopt BDA innovations mostly used quantitative methods with factors that were chosen by the researchers themselves (e.g., Munim et al., 2022; Shukor & Ng, 2022). Hence, using a qualitative approach may provide a better opportunity to identify additional factors reflecting the context of the oil and gas industry. Many BDA researchers used the Delphi method (Corte-Real et al., 2017; Robmann et al., 2018). However, there are no previous studies focused on BDA adoption using the Delphi method or employing the technology-organisation-environment (TOE) framework. To fill this gap, the study highlights how adopting Big Data Analytics can improve decision-making in the oil and gas industry by identifying twenty key factors, including three new ones:, business framework, suitability, and organizational strategy. Overall, the paper seeks to address the following points:

- To identify twenty key factors influencing its adoption across technological, organizational, and environmental contexts.
- To propose the TOE framework, which includes three new factors: organizational strategy, business framework, and suitability.
- To offer a comprehensive approach to technology adoption decision-making in organizations.

2. Theoretical Framework

This section provides an extensive comprehension of the present condition and future possibilities of BDA in the oil and gas sector as well as other sectors. It emphasizes the crucial significance of BDA in predictive analytics, resource management, software development, and operational efficiency. It stresses the necessity for ongoing innovation and adaptation to address growing difficulties.

Sharma et al. (2023) have outlined 17 significant factors that can affect BDA in the tourism and hospitality industries with a focus on big data quality. The authors stress the importance of establishing uniform best-practice guidelines for closing the access divide and facilitating the use of the big data industry. Likewise, in the food industry, Ganeshkumar et al. (2023) reveal that aspects like trialability, observability, and the support of the top management influence BDA adoption. According to them, external support, uncertainty, and organizational preparedness are significant factors driving adoption influences financial and marketing performance.

Giang and Liaw (2022) conducted research on small and medium-sized enterprises (SMEs) and employed data mining methods for the assessment of their readiness to implement BDA. Some of the factors that have been linked to different readiness levels include managerial support, quality of data, organization size, security of data, and cost. According to their findings BDA is internationally more established in the service sector than in the manufacturing sector. Daradkeh (2022) used data analytics on practice data in the context of the Technology-Organization-Environment framework and found that

both technological resources and organizational and environmental factors had a major impact on data science adoption.

Salman et al. (2022), evaluated the readiness of Malaysian libraries on big data, revealing that a high level of technology, organizational, and environmental readiness currently exists. They set a lot of focus on improving technological knowledge and skills in libraries. Another study by Kumar and Aggarwal (2022) was focused on the insurance industry and in this study the authors established that AI, ML and big data were significant technological trends that were leading the insurance industry to go for the digital customer acquisition model.

As for the oil and gas sector, Agbaji (2021) and Abdullah et al. (2023) focused on the revolutionary role of using predictive analytics based on AI, machine learning, data mining for enhancing the identification of wellbore issues as well as enhancing the exploration and production processes. According to Huang et al. (2023) and Nguyen et al. (2020), BDA can help in the efficient management of petroleum and natural gas resources, enhance performance, and mitigate risks at workplace.

According to Vishwanath (2023) and Jordan et al. (2022), the adoption of ML and cloud in the oil and gas industry has done significant progress in reservoir monitoring and evaluation. According to Zhang (2021), the understanding of digitization and BDA in establishing digital and intelligent oil fields has been investigated, especially focusing on advanced data analysis and computation techniques. Zeng et al. (2022) provided a review of the role of intelligent platforms and AI in the management of big data in oil and gas industries, as well as possible establishment of smart oil and gas fields.

Consequently, a study on cloud computing in the context of banking sector offers a comparison in the challenge and opportunities pertaining to use of cloud services. By using interviews with leaders from a major cloud provider and an Omani bank, this study signifies the need to consider the factors that influence data security, infrastructure steadiness, and system integration (Adarbah et al., 2023; Adarbah et al. 2022). The results point to the need for adequite personnel education, and awareness of the specificities of going from traditional to the cloud environment. These insights help enrich the global discourse regarding the role of technology penetration across many industries including the banking and the oil and gases industries paying specific attention to environmental factors, data privacy and business continuity.

To the best of the authors' knowledge, the future of BDA in the oil and gas business depends on successfully addressing these difficulties, guaranteeing the accuracy and dependability of data, and adopting digital transformation for long-term and environmentally friendly progress. There are also no previous studies focused on BDA using the Delphi method or the TOE framework. Therefore, this study will overcome this gap by having this combination.

3. Methodology

This study employed a qualitative methodology and utilized the Delphi method. Three primary rationales support the consideration of the Delphi method as the most appropriate approach for this investigation. Firstly, it is a suitable study design for conducting exploratory studies. It is primarily employed in situations where knowledge is lacking, such as in the context of BDA business value. Furthermore, it becomes valuable in scenarios where the focus lies on subjective and intricate assessments that oppose the exact quantitative outcomes. Furthermore, this approach enables us to effectively tackle the research issue by specifically targeting the acquisition of insights from seasoned professionals who possess extensive expertise in overseeing large-scale data analytics projects (Corte-Real et al., 2017) .

3.1. Participants

The research study had a panel of seven participants, six males and one female, with a range of professional backgrounds and experience from 12 to over 20 years. With degrees ranging from Bachelor's to Master's, these people were experts in fields like Business Computing, Data Science, and Engineering. Participant P-1 was an Omani male who holds a Master's degree in MBA and a BSc in Surveying and Mapping Science. He has accumulated 20 years of experience and currently serves as

the Department Head of Geomatics. Participant P-2, a male individual, originates from Colombia and possesses a Master's degree in Oil and Gas Engineering. He currently holds the position of Petroleum Engineering Data Consultant, with equivalent expertise to that of a P-1. P-3 was an Omani male who holds a Master's degree in Data Science. With 14 years of experience, he currently works as an operations business planning lead.

Participant P-4, a male from Oman, has a Bachelor's degree in data and information management, which sets him apart in terms of his educational achievements. With a tenure of more than two decades, he proudly holds the position of Department Head in Engineering Information Delivery. P-5 was a British male who holds a bachelor's degree in mechanical engineering. Additionally, he has accumulated over 20 years of professional experience and currently serves as a Maintenance Management Systems Lead. The sixth participant, P-6, was a gentleman from Oman who holds a Master's degree in Computer Science and Data Science and has accumulated 12 years of professional experience. He currently holds a position in analytics architecture. Finally, P-7, the only female panelist and an Omani possesses a bachelor's degree in business computing. Boasting a remarkable 17 years of professional experience, she currently holds the esteemed position of Enterprise Data Architect.

3.2. Instrument

We used a qualitative research methodology, specifically applying the Delphi method for data gathering. This strategy is appropriate for conducting exploratory research in situations where there is limited knowledge and a need to make difficult judgments. This method followed an iterative approach, which involved doing three rounds of data collection until a consensus was achieved. The three rounds were planned to take about 30 minutes to an hour, but in reality, they took an hour each. The main objective of Round 1 was to gain general knowledge about the topic of discussion through open-ended questions and brainstorming discussions.

It included three sections: technological-context factors, organizational-context factors, and environmental context factors. Each section has three parts: (1) indicating the level of importance of each factor using a Likert scale from Very Important to Unimportant; (2) prioritizing or ranking the factors from top to bottom; and (3) free-text boxes to provide feedback or comments if required. For Round 3, we showed the panelists the framework based on their suggestions from previous rounds to share their feedback on the results. The online survey including two sections, which were demographics

and brainstorming open-ended questions, had been developed and shared with the panelists at the beginning of the discussion of this round. Section 1 included gender, nationality, educational degree, educational background, years of experience, and current job title. Section 2 included three open-ended brainstorming questions about the technical, organizational, and environmental factors that are impacting the firm's intention to BDA to make quality decisions.

3.3. Procedure

The discussion started with a seven-minute concise introduction that included defining the terms BD and BDA, linking the BDA to the oil and gas industry, presenting the problem statement of the research, and determining the research question and objective. After that, the panelists were asked to open the online questionnaire and provide their demographic information in Section 1 (see Figure 1).

After confirming the completion of Section 1, the participants were given 3-5 minutes to answer the first open-ended question in Section 2. Then, 10 minutes were allocated for group discussion, in which each panelist was asked to share his answers with the group, and they were all allowed to comment and give feedback. They repeated this approach for the second and third questions in Section 2 (see Figure 2). The session of this round took an hour. At the end of the session, the panelists submitted the survey, were thanked for their participation, and were reminded about the schedule and agenda for Round 2. The online questionnaire for Round 2 used a Likert scale to narrow down the findings of the Delphi method. We used the analysis of the findings from Round 1 to construct the questionnaire for Round 2. The factors had been defined (from panelists' explanations and literature) and classified based on the TOE framework.

Figure 1

Questionnaire Section 1: Technological-Context Factors

Section 1: Technological-Context Factors:					
1. Please indicate the importance level of each Technological factor on impacting the firm's intention to adopt BDA to make quality decisions:					
	Very Important	Important	Moderately Important	Slightly Important	Unimportant
1. Availability of Technology Resources.					
2. Compatibility.					
3. Security Concerns.					
4. Data Quality.					
5. Suitability.					
6. Expected Benefits.					
7. Observability					

2. Please prioritize/ rank the factors from 1 (top) to 7 (bottom).							
	1	2	3	4	5	6	7
1. Availability of Technology Resources.							
2. Compatibility.							
3. Security Concerns.							
4. Data Quality.							
5. Suitability.							
6. Expected Benefits.							
7. Observability							
3. Please add your comments (if applicable):							

Figure 2

Questionnaire Section 2: Organizational-Context Factors

Section 2: Organizational-Context Factors:					
1. Please indicate the importance level of each Organizational factor on impacting the firm's intention to adopt BDA to make quality decisions:					
	Very Important	Important	Moderately Important	Slightly Important	Unimportant
1. Human Resources Skills.					
2. Top-Management Support.					
3. Organizational Data-Driven Culture.					
4. Business Framework.					
5. Organizational Strategy.					
6. Financial Readiness.					
7. Change Acceptance.					
8. Size of the Organization.					
9. Absorptive Capacity.					

2. Please prioritize/ rank the order of the factors from 1 (top) to 9 (bottom):									
	1	2	3	4	5	6	7	8	9
1. Human Resources Skills.									
2. Top-Management Support.									
3. Organizational Data-Driven Culture.									
4. Business Framework.									
5. Organizational Strategy.									
6. Financial Readiness.									
7. Change Acceptance.									
8. Size of the Organization.									
9. Absorptive Capacity.									
3. Please add your comments (if applicable):									

The session for Round 2 started with a 5-minute concise introduction to demonstrate the analysis of the findings from Round 1. Then, the panelists were given 10–15 minutes to answer the questionnaire and submit it. The session of this round took only 30 minutes. The session ended by thanking the panelists for their participation and discussing the schedule and agenda for Round 3. In the opening of Round 3, the researcher presented the panelists with the framework that was developed using their inputs from prior rounds. The panelists were given an online survey including a single open-ended question, allowing them to share their feedback on the results. Subsequently, the debate was initiated to facilitate introspection and enable the participants to articulate and disseminate their viewpoints to the collective. The duration of this round was a mere 30 minutes, and it closed with expressions of gratitude from the experts for their involvement.

Figure 3

Questionnaire Section 3: Environmental-Context Factors

Section 3: Environmental-Context Factors:

1. Please indicate the importance level of each Environmental factor on impacting the firm's intention to adopt BDA to make quality decisions:

	Very Important	Important	Moderately Important	Slightly Important	Unimportant
1. Regulatory Environment.					
2. Environmental Uncertainty.					
3. Risks in Outsourcing.					
4. Competitive Pressure.					

2. Please prioritize/ rank the factors from 1 (top) to 4 (bottom).

	1	2	3	4
1. Regulatory Environment.				
2. Environmental Uncertainty.				
3. Risks in Outsourcing.				
4. Competitive Pressure.				

3. Please add your comments (if applicable):

4. Results

The collected data in round 1 was purely qualitative, which required a thematic analysis to present it. As this research was based on the TOE framework, the discussion in this round was classified into three themes: technological context factors, organizational context factors, and environmental context factors. Henceforth, the analysis was also divided based on the three classifications.

The factors were mentioned by the panelists during Round 1 when they were asked to identify the technological factors impacting the firm's intention to adopt BDA to make quality decisions. A total of ten factors are mentioned in this context.

P-1 and P-3 also pointed out the availability of technology resources such as hardware, software, and networks as another technological factor. The first panelist said, "*The availability of reliable software and hardware is crucial for BDA"*. This factor relates to the factor mentioned by the second panelist, who said, *"The ability to leverage on new digital technologies is imperative for our organization to remain relevant in the market"*. Moreover, panelists (P-2, P-6, and P-7) also emphasized that one of the critical factors of success is the compatibility of the new technology solutions, including BDA, with the existing organizational infrastructure. The three factors discussed above lead to a general statement that underpins the importance of the organizational technological agility in the adoption of BDA solutions.

Panelist (P-4) stated that before adopting any BDA solution, the company should carefully consider the cost of adoption, claiming that software licenses, support, and maintenance are becoming very expensive. This factor is linked with the factor highlighted by panelists (P-1), which is the organizational policy to adopt BDA Open Source Software, in which the cost will be minimized. However, when linking this factor with the Security Concerns factor mentioned by P-6 and P-7, the adoption decision will somehow be difficult and require more feasibility studies.

Furthermore, the panelists (P-2 and P-6) highlighted that the company should consider the human resources skills level to consume such technologies. This factor has a crucial impact on the intention of companies to adopt BDA, as it is heavily dependent on the decisions made by these people, but if their skills are limited, then the generated benefits from BDA technologies will be poorly impacted.

Another factor mentioned by panelists (P-1 and P-5) is data quality. They gave several terminologies to explain the significance and impact of this factor on the firm's intention to adopt BDA to make quality decisions. They stated that the readiness and cleanness of data, data integrity, trusted data, and the organizational computing power to transform the data into information are very important aspects that will ensure the usefulness of BDA solutions in decision-making processes.

The compatibility of the technology with business processes is another aspect that panelists (P-3 and P-4) have highlighted. For example, (P-3) said that the level of complexity in operational processes identifies the type of technology suitable to handle those processes. Again, panelists (P-4) stated that the end-to-end business processes should be clearly defined to enable the organization to adopt a suitable BDA technology that will help to derive correct decisions and generate business values. On the other hand, the same panelist raised a concern about the difficulty of quantifying and demonstrating the short-term benefits of BDA solutions to management. This argument encouraged him to explain the impact of the expected benefits of BDA on the management's intention to adopt such solutions. When asked to identify the organizational factors influencing the firm's intention to adopt BDA to make quality decisions during Round 1, the panelists highlighted the following factors. A total of ten factors are mentioned in this context.

Six panelists (P-1, P-2, P-3, P-4, P-5, and P-6) highlighted that skilled resources are an important factor that impacts the firm's intention to adopt BDA to make quality decisions. They stated that the staff's capabilities to set up the analysis and interpretations are a crucial success factor for BDA. In many cases, there is a shortage of analytics skills in oil and gas organizations, which triggers the need to up-skill or re-skill the human resources within the organization.

Another factor that the panelists (P-4, P-6, and P-7) mentioned was organizational strategy. Panelist P-4 said that organizations should have an effective transformation strategy before adopting new BDA solutions. P-6 pointed out that organizations need to build a clear analytics strategy (centralization, silos, or mixed) that promotes data-driven decisions. To stress this, panelist P-7 emphasized that the inexistence of clear business strategy and objectives will lead to unclear organizational KPIs and silo working environments.

Panelists (P-2, P-3, P-5, and P-6) identified the business model factor. P-2 argues that *"there must be a balance between a centralized team to provide standards and governance and teams to promote innovation and efficiency at the business scale."*. As panelist P-3 stated, this will aid in leveraging BDA skills at the organizational level. The panelists (P-1 and P-5) who have discussed this factor have also mentioned the size of the organization factor. Panelist P-5 clearly said that the consistency of approaches and endorsed conclusions regarding centralization depends heavily on the size of the organization.

In addition, panelists (P-2 and P-3) said that the organizational data-driven culture is another factor, as the adoption of new technologies such as BDA relies on the organizational culture to respond to technology changes. In contrast, panelists P-1, P-4, and P-6 mentioned another factor that might prevent the adoption of BDA. This factor is fear of change. Panelist P-4 explained that the firm's adoption of BDA may trigger the fear of people losing their jobs or becoming less important in the company.

Top-management support is another element that the panelist (P-2) has highlighted. According to him, *"the mature organization management level eager to support new technologies is mandatory"* to ensure the successful adoption of BDA. Top-management support is typically associated with the anticipated value that BDA will provide to the organization, as stated by panelists P-2 and P-6.

Panelists (P-6 and P-7) said that data management, governance, and literacy are important factors that impact the quality of decisions derived from BDA. Panelist P-7 clearly stated that the lack of data management processes and undefined data governance (including roles and responsibilities) in an organization may lead the organizational investment in BDA solutions to a loss. Compatibility, which panelist P-1 also mentioned, is somehow related to this factor. He argues that the integration of BDA solutions with other existing systems in the organization is another factor that the organization needs to consider. When asked to identify the environmental factors influencing the firm's intention to adopt BDA to make quality decisions during Round 1, the panelists highlighted the following factors. A total of six factors are mentioned in this context.

The majority of panelists (P-1, P-2, P-3, P-4, P-6, and P-7) highlighted the same factor in the environmental context, which is government policies and regulations. Panelist P-7 elaborated on this factor by saying that organizations need to comply with the regulatory requirements established by the Ministry of Oil and Gas (MOG) and the National Records and Archives Authority (NRAA), organizational policies and standards (data and information retention schedule), and the future General Data Protection Regulation (GDPR).

The instability of oil prices is another factor that four panelists (P-1, P-3, P-4, and P-6) mentioned, and they all concurred that it influences organizations to lower the cost of operations and projects and may determine the viability of any investment.

According to panelists (P-2, P-5, and P-6), competition is yet another factor that influences the firm's intention to adopt BDA. Panelist P-2 clearly stated that *"competition is the real trigger for change, the most competitive environment, and more sense of innovation"*. Conversely, panelist P-6 said that the impact of this factor is very low in the case of governmental oil and gas companies as the competition becomes less. Panelist P-5 explained the competition differently, as he said that there is competition from the BDA market itself, in which service providers compete in marketing their BDA solutions and make so many promises.

The contracting framework is another element that panelists (P-2 and P-5) have mentioned. They highlighted that there are some restrictions related to giving permissions to third parties to access data and potential hosts off the company premises and adopting new technologies such as cloud computing.

Again, some panelists (P-2 and P-4) mentioned that data quality and reliability, including data standardization and classification, are the real foundation for BDA. The success stories, which refer to the positive effects of BDA solutions used in other firms and influence the intention of other firms to adopt BDA, are another factor that panelist P-3 mentioned.

The total number of factors highlighted by the panelists during the brainstorming session in Round 1 was 26. However, there were some redundancies, different names, different definitions, and different classifications of certain factors, which the panelists mentioned in different contexts.

The first step was to combine the redundant factors into a single factor. There are three examples of this. The first example is data quality, data management, data governance, data literacy, and data reliability, which the researcher combined into one factor, which is data quality, and classified it under a technological context, the same as in TOE-based previous studies. Another example is human resources skills and skilled resources, which have been mentioned under technological and organizational contexts, but according to the TOE framework, the human resources skills factor is normally classified under the organizational context. The third example is organizational policy and organizational strategy, which decided to be organizational strategy under the organizational context.

Secondly, we renamed the factors by the previous TOE-based studies when applicable. To elaborate, the panelists highlighted factors such as the cost of adoption, fear of change, government policies and

regulations, the instability of oil prices, the contracting framework, and Success Stories. These factors have been renamed to Financial Readiness, Change Acceptance, Regulatory Environment, Environmental Uncertainty, Risks in Outsourcing, and Observability, respectively. Thirdly, the definitions of the factors offered by the panelists were also consistent with definitions offered in earlier TOE-based studies.

Table 1 illustrates how cloud computing improves operational efficiency and cost-effectiveness while also providing support for a wide range of banking services. The text emphasizes the need for data security, namely the need to comply with strict banking laws and maintain redundancy. From a financial perspective, the process of adopting cloud technology is complex and requires careful consideration of any hidden expenses. It also requires ensuring that corporate goals are in line with the chosen cloud strategy. Finally, the text addresses the difficulties associated with transitioning between different cloud service providers, particularly in managing databases and the limitations imposed by a small number of major providers and legislation governing data storage.

Table 1
Brief Insights on Themes

Theme	Brief Description
Cloud Computing Comprehension	Cloud computing enables banking agility and offers cost savings on IT. It provides insights into customer behavior and supports diverse banking services.
Security Paradigm	Participants expressed concerns over data protection in the cloud. Emphasis was on redundancy and alignment with strict banking regulations.
Budgetary Implications	The financial aspects of cloud adoption can have hidden costs. Aligning business and cloud goals and understanding transition expenses are challenges.
Infrastructure Evaluation	Migrating between cloud providers poses challenges, especially with database shifts. Data storage laws and limited large-scale providers further constrain options.

Table 2 presents the various elements that impact the technological environment for the implementation of BDA in organizations. The first step involves evaluating the sufficiency of the existing technological resources, including hardware, software, and IT infrastructure, that are required for the implementation of BDA. After that, compatibility is checked, specifically looking at how well BDA's features match up with the current IT infrastructure, allowing it to be easily added to and grown within the company.

Table 2
Brief Insights on Technological Context Factors

Factors	Brief Description
The availability of Technology Resources	The firm's technology resources are adequate for the task of adopting BDA (i.e., hardware, software, and IT infrastructure).
Compatibility	The characteristics of BDA are perceived as being consistent with the existing IT architecture in an organization (i.e. scalability, integration into the existing technologies and platforms such as master data management tools, and data integration tools).
Security Concerns	The degree of concern in ensuring compliance with security and data privacy regulations in relation to BDA adoption.
Data Quality	The degree to which the data needed for BDA are accessible, consistent, and complete. It includes data governance, data literacy, data reliability, and data trustworthiness.
Suitability	The extent to which the BDA technology is suitable for organizational business processes.
Expected Benefits	The degree to which the BDA technology is expected to benefit the organization.
Observability	The characteristics of BDA are perceived as being beneficial after observing how other organizations use it (i.e., Success Stories).

The utmost importance lies in addressing security problems, particularly in ensuring adherence to data privacy regulations while implementing BDA. The accessibility, consistency, and completeness of the data are factors that ensure data quality. This is important because it establishes the reliability and trustworthiness needed for effective analytics. An assessment is conducted to determine the compatibility of BDA technologies with the organization's business processes. Subsequently, the potential advantages that the organization expects to gain from using BDA are examined. Lastly, the concept of observability is examined about how the effective implementation of BDA in other companies can impact its perceived worth and encourage its adoption.

Table 3 defines vital organizational factors that impact the implementation of BDA. The statement underscores the significance of possessing proficient personnel, managerial backing, and a data-centric culture. The agility of the IT infrastructure and the strategic focus on BDA are both crucial. For successful integration of BDA, it is crucial to have the financial capability to invest in BDA, a commitment to embrace change, an organization of sufficient size to support BDA projects, and the ability to effectively adopt and utilize new technology.

Table 3
Brief Insights on Organizational Context Factors

Factors	**Brief Description**
Human Resources Skills	The firm's human resources are adequate for the task of adopting BDA (i.e., analysts, data scientists, data science experts, and skilled users).
Top Management Support	Managers are willing to allocate sufficient resources and encourage the initiative adoption of BDA.
Organizational Data Culture	A pattern of behaviors and practices by a group of people who share the belief that having, understanding, and using BDA plays a critical role in the success of their organization.
Business Framework	Refers to the IT organizational structure and digitization of business processes (i.e., centralized, silos, or mixed).
Organizational Strategy	An organization strategy that is oriented to business analytics and using BDA for strategic decisions (i.e., business strategy of prioritizing BDA adoption)
Financial Readiness	The financial resources available to pay for BDA costs, for implementation of any subsequent enhancements, and ongoing expenses during usage.
Change Acceptance	Organization members can easily handle the changes triggered by the adoption of BDA.
Size of the Organization	The firm's annual revenue and number of employees that could support the adoption of BDA.
Absorptive Capacity	The firm's ability to recognize the value of new and emerging technologies such as BDA, absorb it, and early adopt it to add value to the business.

Table 4 presents the environmental context factors that impact the adoption of BDA in companies. The text explores the regulatory environment, emphasizing the crucial role of government support through legislative frameworks in facilitating the adoption of BDA. Fluctuating oil prices, which fall under the category of environmental uncertainty, impact financial decisions concerning investments in BDA. The risks associated with outsourcing are examined, with a focus on the security and privacy considerations that arise when utilizing third-party or open-source big data analytics technologies. Lastly, organizations are motivated to use Big Data Analytics (BDA) to sustain or improve their market position due to the influence of Competitive Pressure.

We ranked the parameters revealed in the initial phase of our investigation based on their significance. The procedure entails three sequential steps: firstly, generating a comprehensive list of all potential factors; secondly, refining this list to include only the most pertinent ones; and lastly, arranging them in a hierarchical manner based on their significance. The data collected during this phase were

quantitative, which necessitated the use of specialized statistical techniques to examine any agreement among the findings.

To assess the level of agreement, we examined the standard deviation (SD). This statistic provides insight into the extent of divergence among our experts' viewpoints. Typically, a smaller SD suggests that the experts' judgments are more closely clustered around the average rating, indicating a higher level of agreement among them.

During the analysis of the second round of the Delphi method, we computed various statistical measures for each factor, including the mean, standard deviation, rank, and Kendall's W. These computations enhance our ability to effectively assess the data and comprehend the aggregate viewpoint of our panel of experts.

Table 4

Brief Insights on Environmental Context Factors

Factors	Brief Description
Regulatory Environment	The governmental agencies encourage firms to adopt BDA by providing related support (i.e. legal environment, industry regulation, data protection regulations).
Environmental Uncertainty	The instability of Oil prices is impacting the firm's financial decisions (i.e. making investments in BDA adoption).
Risks in Outsourcing	The perceived degree of security and privacy risks associated with outsourcing (outsource BDA or the use of third-party tools or buy off-the-shelf packages such as Open Source Software).
Competitive Pressure	The perceived pressure from business competitors forces a firm to adopt BDA for the sake of maintaining competitiveness.

Based on the results of Table 5, the average is between 1.57 and 3.43. We initially decided to eliminate the factors whose average values are more than 3, which means that the size of the organization factor can be eliminated. By looking at the SD values, it is noticeable that the values are distributed between 1.69 and 0.53. That means 9 out of the 20 factors have an SD greater than 1, which indicates that the consensus for these factors has been reached but is not perfect. Kendall's coefficient of concordance (W) values for the technological context factors, organizational context factors, and environmental context factors are 0.17, 0.17, and 0.40, respectively. Thus, they indicate that the consensus has been reached, but it is not perfect.

Table 5

Statistical Results from Delphi Method-Round 2

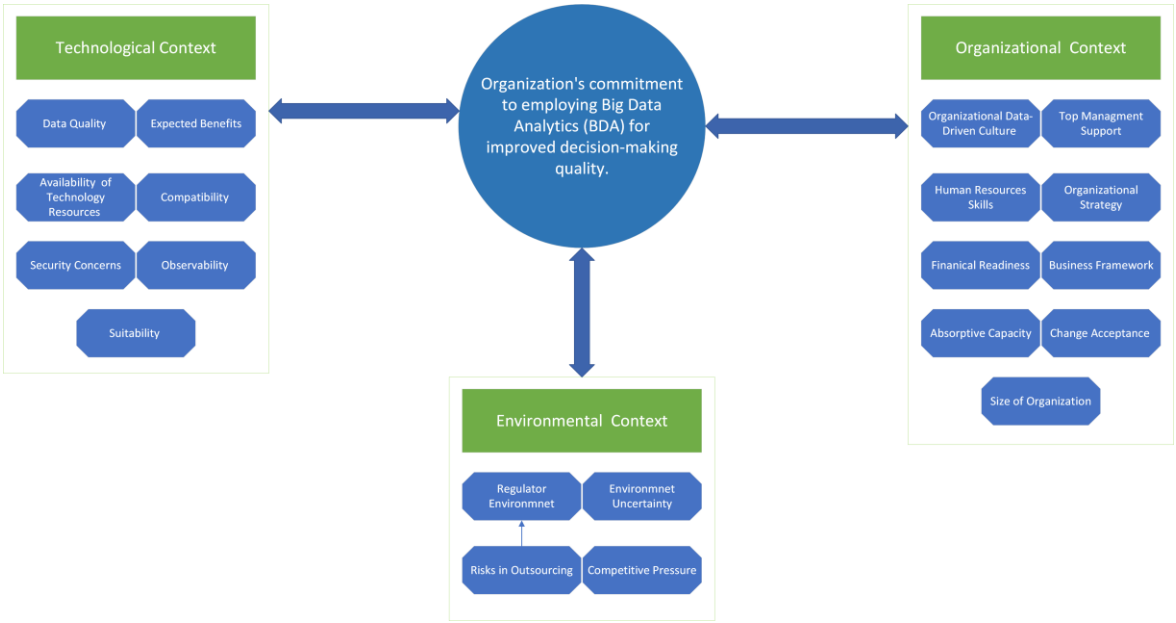
Factors	Mean	Standard Deviation	Rank
Technological Context			
Data Quality	1.57	1.13	1
Expected Benefits	2.00	1.15	2
Availability of Technology Resources	1.57	0.53	3
Compatibility	1.86	0.69	4
Security Concerns	2.43	1.62	5
Observability	2.86	1.35	6
Suitability	2.43	1.27	7
Kendall's coefficient of concordance (W)			0.17
Organizational Context			
Organizational Data-Driven Culture	1.86	0.69	1
Top-Management Support	1.43	0.53	2
Human Resources Skills	1.57	0.53	3
Organizational Strategy	2.00	0.82	4
Financial Readiness	2.57	0.53	5
Business Framework	2.43	0.53	6

Absorptive Capacity	2.57	1.40	7
Change Acceptance	2.43	0.79	8
Size of the Organization	3.43	1.27	9
Kendall's coefficient of concordance (W)			0.40
Environmental Context			
Regulatory Environment	2.00	1.15	1
Environmental Uncertainty	1.86	0.90	2
Risks in Outsourcing	2.43	0.98	3
Competitive Pressure	2.43	1.27	4
Kendall's coefficient of concordance (W)			0.17

As this round was conducted to present the findings to the panelists and obtain their confirmation on the results, the panelists collectively confirmed the order of the factors except the organizational strategy factor. They said this factor is very important and should be ranked immediately after the organizational data-driven culture. Therefore, the order of this factor was changed from rank number 4 to 2, and all other factors remained unchanged. Finally, the factors were reclassified based on the definition of the framework contexts (see Figure 4).

Figure 4

Proposed TOE Framework for BDA Adoption in Decision-Making within Oil and Gas Organizations



5. Discussion

The research results confirm previous insights and research on the factors and issues surrounding BDA implementation in the oil and gas industry. In their view, Sumbal et al. (2019) pointed out that handling big data also entails the application of superior analytical ability, a strong IT infrastructural support system, domain knowledge, and good business insight to understand the findings of the analytics. These are essential in the actualization of BDA and the TOE framework aligns well with what the panelists had highlighted.

In the technological context, the most important factor revealed was data quality which is in accordance with the difficulties of the companies operating in the oil and gas sector since they deal with the data that comes from various sources in various formats. The data quality is high, but the problem of inconsistency appears due to differences in standards of appliances, sensors, and technologies used in business processes. This leads to data that is dispersed across multiple databases but may lack a

standardized and organized format, which is detrimental to data consolidation and quality. On this view, the current literature, including Adarbah et al. (2023), and Shah et al. (2022), is inconclusive. Low quality data, on the same note, means that there will be wrong conclusions being drawn, hence negating the effectiveness of decision-making (Alguliyev et al., 2016).

The integration of the IoT and the MANET presents a possible fix to the data quality problems. IoT infrastructure entails the interconnection of various sensors and devices, and, thus, can enforce the methodological consistency of data capturing processes to enhance the quality of data gathered. This can help to reduce the issues caused by varied data points aches from different sources. However, IoT also offers an efficient way of monitoring situations and collecting data, especially in such dynamic fields as the oil and gas industry (Adarbah & Ahmad, 2019; Adarbah et al., 2022). MANETs on the other hand offer dependable information transfer from hard to reach and ill accessible areas resulting in more accurate and timely data.

In this study, data quality proved to be more important than expected benefits for BDA adoption, while the study by Sun et al. (2018) ranked expected benefits as the most influential factor. This clearly points towards tangible benefits as a key factor considered essential for the adoption of BDA. The other important variable, IT assets, commonly refer to as technology resources, was the next measure. Compatibility was ranked fourth indicating that BDA solutions have to fit within the existing business dynamics and architecture, with Sun et al on the same.

In the organizational context the issues such as data-driven culture, top management support, financial readiness were important. If an organization embraces data-driven culture, BDA initiatives can develop strategies that can support organizational goals and objectives Through top management support, resource implications to BDA initiatives are provided, and the initiatives are encouraged. Another important factor that affects BDA adoption intentions is the number and quality of employees in the workplace.

Most of the concerns raised by panelists revolve on how to ensure that BDA is integrated into the organizational structure, this provide direction on the way that BDA will be adopted. The business framework, organizational structure between transactional and integrated units and how they communicate with each other also affects BDA adoption. Greater firms who have more capital available to them will adopt innovations at a faster rate since they can better withstand any hazards. On the other hand large organizations can undertake the project since they have enough capital and resources to sink while smaller organizations may shy away due to the huge capital outlay.

Other, four factors were found to have a significant impact; regulatory environment, environmental uncertainty, risks in outsourcing, and competitive pressure. Kumar and Krishnamoorthy (2020) also highlighted the fact that competitors should be implementing BDA since it boosts the probability of firms adopting BDA. Market rivalry helps organizations to come up with various strategies that can enable them to remain relevant in the market. Nevertheless, this pressure may not be felt as keenly among the public sector firms in oil and gas as it would be felt in the private sector.

This study contributes to BDA research by identifying twenty key factors influencing its adoption, enriching the TOE framework with three new factors: These will include such factors as organizational strategy, business framework, an aspect of suitability. The structure of the Delphi method was qualitative which helped in getting an understanding of these factors. These insights help the policy makers, researchers, and IT suppliers to understand the dynamics of the ever-changing oil and gas supply chain worldwide and provide a robust framework to measure BDA adoption intentions.

Therefore, the study has some limitations as follows; first, the study was conducted in an Omani context and among a single company, which may limit the generalizability of the results. The study suggested that future research should adopt the choice of more organizations to increase the practicality of the framework.

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