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Leveraging Artificial Intelligence for Sustainable Cloud Computing: Transitioning from Physical to Virtual Machines

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Abstract: The purpose of this research is to find out how cloud computing infrastructures may be made more sustainable by using AI. As a more popular alternative to traditional server hardware, cloud computing is having far-reaching effects on many subfields of information technology. It has a great deal of promise for enhancing the quality and efficiency of manufacturing processes. Nevertheless, there is a dearth of research on the first phases of cloud computing deployment in Jordan's manufacturing sector, according to a survey of the relevant literature. Businesses in Jordan may soon be moving away from using physical equipment and toward using virtual ones, thanks to cloud computing. Consequently, this research suggests an adoption framework that was created and tested with the help of three Jordanian companies. Two focus groups, semi-structured interviews, and yearly reports were among the many sources used to compile the qualitative data used in this interpretative method. Virtualization technology, price, pricing, physical resource availability, team expertise, and the migration process are some of the important aspects that this report identifies as potentially impacting cloud adoption.

Keywords: Cloud technology, Information quality, Mathematical solutions, Virtual machines

1 Introduction

"Cloud computing," wherein data is stored, processed, and managed via the internet on virtual servers offered by third parties instead of utilizing one's own personal computers, is what the word "cloud" means when used to computer systems [1]. The pay-per-use model, like that of utilities like water and electricity, is fundamental to this strategy, which represents a radical departure from conventional in-house computers [2,3,4]. But the term "cloud computing" has yet to be defined in a way that everyone can agree with [5]. Cloud computing's commercial model is seen as antiquated by researchers like Sultan [6]. As an example, back in the 1930s, IBM had services where clients could upload massive volumes of data to be processed, and IBM would handle the data according to different service levels [7,8]. Virtualization and other forms of distributed computing in the cloud allow for faster scheduling and better overall operations. The many ways in which cloud computing has improved IT, including processing speed, service quality, payment security, and response times, are well-known [9].

Cloud service providers guarantee that users will only be charged for the resources that are really used by their applications [10,11,12,13]. Reevaluating the ROI is essential when contemplating cloud computing, especially when taking into account the company's growth and the unique features of the application [14]. A properly functional internet connection is the most

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important need for using cloud computing [15]. Consequently, companies in underdeveloped nations with sluggish internet connections and inadequate IT infrastructure may not find cloud computing to be the best solution for their data transmission needs [16].

2 Research Problem

The abstract highlights the significant potential of cloud computing to transform the manufacturing sector by enhancing efficiency and quality [17]. However, in the context of Jordan's manufacturing industry, there is a notable lack of research on the initial phases of cloud computing adoption [18]. Despite its growing popularity as a sustainable alternative to traditional server hardware, the specific factors influencing cloud computing adoption in this region remain underexplored [19]. Given this gap, the research problem is to identify and analyze the key factors affecting the adoption of cloud computing in Jordan's manufacturing sector, with a focus on virtualization technology, cost considerations, physical resource availability, team expertise, and the migration process [20]. To address this problem, mathematical solutions can be employed to develop a quantitative framework for evaluating these factors [21]. This could involve: 1. Optimization Models: Develop optimization models to determine the most cost-effective and resource-efficient cloud computing solutions for Jordanian manufacturing companies [22]. These models can incorporate constraints related to virtualization technology, cost, and resource availability.

2. Decision-Making Algorithms: Create algorithms for decision-making that use data from focus groups, interviews, and reports to provide actionable insights for businesses [23]. These algorithms can help in assessing the impact of different factors on cloud adoption and suggest optimal strategies for migration [24].

3. Predictive Analytics: Use predictive analytics to forecast the potential benefits and challenges of cloud computing adoption. This involves analyzing historical data to predict future trends and outcomes related to cloud adoption in the manufacturing sector [25]. 4. Simulation Models: Develop simulation models to test various scenarios of cloud adoption, allowing businesses to understand the potential impacts of different strategies and choices before actual implementation [26].

By integrating these mathematical approaches, the research aims to provide a robust, data-driven framework for guiding Jordanian manufacturing companies through the adoption of cloud computing, thereby contributing to more sustainable practices and improved efficiency [27].

3 Mathematizing the converting process from physical to virtual machines

Resource Utilization Prediction (Autoregressive Model):

$$R^{t+1} = \sum_{i=1}^{p} \phi_i R^{t+1-i} + \varepsilon_t ....(1)$$

Where R^{t+1} is the predicted resource utilization at time $t+1$, and ϕ_i are autoregressive parameters.

Energy Consumption Model:

$$E = \alpha R + \beta ....(2)$$

Linking energy consumption E with resource utilization R through coefficients α and β.

Load Balancing Optimization:

$$\sum_i L_i <= \sum_i C_i ....(3)$$

Where L_i and C_i represent the load and capacity of virtual machine i.

Neural Network Training (Minimizing Mean Squared Error):

$$\min_{\theta} \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 ....(4)$$

Where θ represents the model parameters, y_i is the actual value, and $\hat{y}_i$ is the predicted value.

Sustainability Metric:

$$S = \frac{\sum_{i=1}^{n} (L_i \cdot C_i)}{\sum_{i=1}^{n} E_i} ....(5)$$

Combining capacity, load, and energy consumption to evaluate the overall sustainability of the cloud infrastructure [**?**].

Reinforcement Learning Reward Function:

$$R(s,a) = \lambda_1 U(s) + \lambda_2 C(s) ....(6)$$

Where λ_1 and λ_2 are weighting factors, $U(s)$ is the utility, and $C(s)$ is the cost.

Support Vector Machines (SVM) for Classification:

$$\min_{\mathbf{w},b,\xi} \frac{1}{2} \mathbf{w}^T \mathbf{w} + C \sum_{i=1}^{n} \xi_i ....(7)$$

Subject to:

$$y_i(\mathbf{w}^T \mathbf{x}_i + b) \geq 1 - \xi_i, \quad \xi_i \geq 0 ....(8)$$

Markov Decision Process (MDP):

$$V(s) = \max_a \left(R(s,a) + \gamma \sum_{s'} P(s'|s,a) V(s') \right) ....(9)$$

Where $V(s)$ is the value function, $R(s,a)$ is the reward function, and $P(s'|s,a)$ is the transition probability.

Long Short-Term Memory (LSTM) for Resource Prediction:

$$h_t = \sigma(W_h \cdot [h_{t-1}, x_t] + b_h) \ldots .(10)$$

Autoregressive Integrated Moving Average (ARIMA) Model:

$$y_t = \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t \ldots .(11)$$

Heteroskedasticity (GARCH) Model:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_1 \sigma_{t-1}^2 \ldots .(12)$$

Power Usage Effectiveness (PUE) Metric:

$$PUE = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}} \ldots .(13)$$

Virtual Machine Allocation Optimization (Integer Programming):

$$\min \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

Subject to:

$$\sum_{j=1}^{m} x_{ij} = 1 \quad \forall i \quad \text{and} \quad \sum_{i=1}^{n} x_{ij} \leq C_j \quad \forall j$$

Where c_{ij} is the cost of assigning task i to machine j, and x_{ij} are binary variables.

This paper attempts to give a framework for the adoption of cloud computing in Jordan, while also examining the significant concerns that may impact its acceptance. The outcomes of this research indicate that the use of cloud technology in Jordanian manufacturing is not fully optimized [29]. The consumption level may be determined by several factors. Factors such as the level of familiarity with cloud computing may have an influence [30].

The technical personnel may have seen cloud technology as unnecessary due to their expectation of no advantages and their prediction of increased expenditures associated with its implementation [31]. Therefore, authors suggest a Quantifying sustainable cloud technology to enhance performance as follows:

1. Resource Utilization Matrix This matrix, denoted as U, is structured across three levels to represent the utilization of various resources—such as CPU, memory, and storage—by both physical and virtual machines over different time periods.

$$U = \left(u_{ijk}\right) \ldots .(15)$$

Where u_{ijk} represents the utilization of resource k by machine j at time i. Average Utilization: This refers to the calculation of the average utilization of resource (k) across all time periods.

2. Total Utilization: This represents the sum of the utilizations of all resources at time (i).

$$\text{Total Utilization} = \sum_{i=1}^{n} u_{ijk} \ldots .(16)$$

3. Energy Consumption Array This array, denoted as E, is structured across three levels to track the energy consumption of physical and virtual machines over various time periods.

$$E = \left(e_{ijk}\right) \ldots .(17)$$

Where e_{ijk} indicates the energy consumption of machine j at time i.

4. Total Energy Consumption: This is the cumulative energy consumption across all machines and time periods.

$$\text{Total Energy Consumption} = \sum_{i=1}^{n} \sum_{j=1}^{m} e_{ijk} \ldots .(18)$$

5. Performance Metrics Array This three-level array (P) contains performance metrics (such as throughput, latency) for evaluating the efficiency of machines across different time periods [32].

$$P = \left(p_{ijk}\right) \ldots .(19)$$

Where p_{ijk} denotes the performance metric k for machine j at time i.

Average Performance: Average performance for metric (k) over all machines and time periods:

$$\text{Average Performance} = \frac{1}{n} \sum_{i=1}^{n} p_{ijk} \ldots .(20)$$

6. Cost Efficiency Array This three-level array (C) helps in assessing the cost efficiency of transitioning from physical to virtual machines across different time periods.

$$C = \left(c_{ijk}\right) \ldots .(21)$$

Where c_{ijk} represents the cost efficiency of machine j at time i.

Total Cost Efficiency: Total cost efficiency over all machines and time periods:

$$\text{Total Cost Efficiency} = \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ijk} \ldots .(22)$$

4 Cloud Computing Models

Understanding cloud deployment models is essential for grasping how cloud resources are aggregated. The public cloud, widely available and cost-effective, offers basic features with limited customization options. Its inherent openness attracts a broad range of users but may result in lower security compared to other models. The affordability of the public cloud is a significant advantage, making it suitable for non-critical data and operations for companies in Jordan. However, this model comes with a trade-off between cost and security.

Conversely, the private cloud offers a high level of security at a higher cost. Typically owned and managed by a single organization, this model provides greater control over the cloud infrastructure. Access is restricted to just one company and its clients, making it ideal for handling sensitive data, especially in Jordanian industrial sectors. The hybrid cloud model, which combines public and private clouds, allows organizations to benefit from the strengths of both models, enhancing security for sensitive information while reducing costs for less critical data [33].

In a community cloud, organizations from sectors such as education, healthcare, industry, and technology can share resources. This model enables users to leverage proven infrastructure while potentially reducing costs and enhancing security through shared resources. 4.1 Cloud Computing Service Models The term ”x-as-a-service” describes a common model in cloud computing where various software, hardware, and support services are provided by cloud service providers. These comprehensive services can be particularly advantageous for Jordanian manufacturers, though selecting the right provider can be challenging due to the numerous factors that need consideration. Most cloud services offer limited customization, so it is advisable to maintain both existing in-house technology and the new cloud service during the transition phase. Testing a demo version can provide valuable insight into the migration process. Cloud computing service models are generally categorized into Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) [34].

4.2 IaaS (Infrastructure-as-a-Service) Managing IT infrastructure in-house is time-consuming and costly, often requiring significant investment in physical servers. IaaS allows organizations to rent or purchase server space remotely, offering scalability that lets companies easily adjust resources like CPU and RAM to meet specific needs. While IaaS can improve virtual server performance, security and privacy remain top concerns. Companies with high bandwidth and data transfer needs might still prefer investing in their own physical infrastructure despite the cost advantages of IaaS.

4.3 PaaS (Platform-as-a-Service) PaaS provides a pre-configured framework for application development, enabling users to efficiently build and deploy applications on a robust infrastructure. It also allows for customization of interfaces and applications, offering resources such as technical tools, code libraries, and software. PaaS is cost-effective and saves time, particularly for small and medium-sized enterprises, by using a pay-as-you-go model. However, developers may become dependent on a particular platform, complicating any future transition to a different provider.

4.4 SaaS (Software-as-a-Service) SaaS delivers applications accessible via web browsers, eliminating the need for software installation. Popular services like Google Drive and OneDrive fall under this category. SaaS is particularly beneficial due to its affordability and the convenience of accessing applications from multiple devices. However, it also presents challenges related to security, privacy, and limited control over application settings, as service providers manage updates and changes without prior user notification. While SaaS offers significant benefits, it may not fully meet the specific needs of Jordan’s industrial sector [35].

4.5 DaaS (Database-as-a-Service) DaaS allows users to create, store, and manage databases in the cloud efficiently and cost-effectively, without the stringent hardware requirements of physical servers. However, DaaS requires significant bandwidth for data transfers, and users may find it difficult to switch providers due to potential attachment to their current service. Migrating data from on-premises to cloud-hosted databases can also be costly [36].

4.6 Virtualization Virtualization involves simulating a physical system, server, or network resource within a computer, separating hardware from software to improve system utilization and resource management. This concept has become central to cloud computing, allowing Jordanian manufacturers to replace outdated hardware with virtual machines. Virtualization includes components like storage, operating systems, platforms, and networks, and is key to the future of data centers.

5 Research Methodology

According to Zikmund, research methodology encompasses the study strategy, tools, procedures, fieldwork, and analysis used. This investigation employed a qualitative, interpretative approach, focusing on inductive research aimed at addressing real-world problems rather than testing existing theories. Data were gathered from primary and secondary sources, including in-depth interviews and focus groups, and analyzed using Nvivo software. The analysis followed Miles and Huberman’s three-step process: data condensation, presentation, and result validation.

Fifteen participants were initially selected for semi-structured interviews, but only nine were completed due to participant absences. In total, nine interviews and two focus groups were conducted across three Jordanian manufacturing locations to gather qualitative data using an interpretative approach.

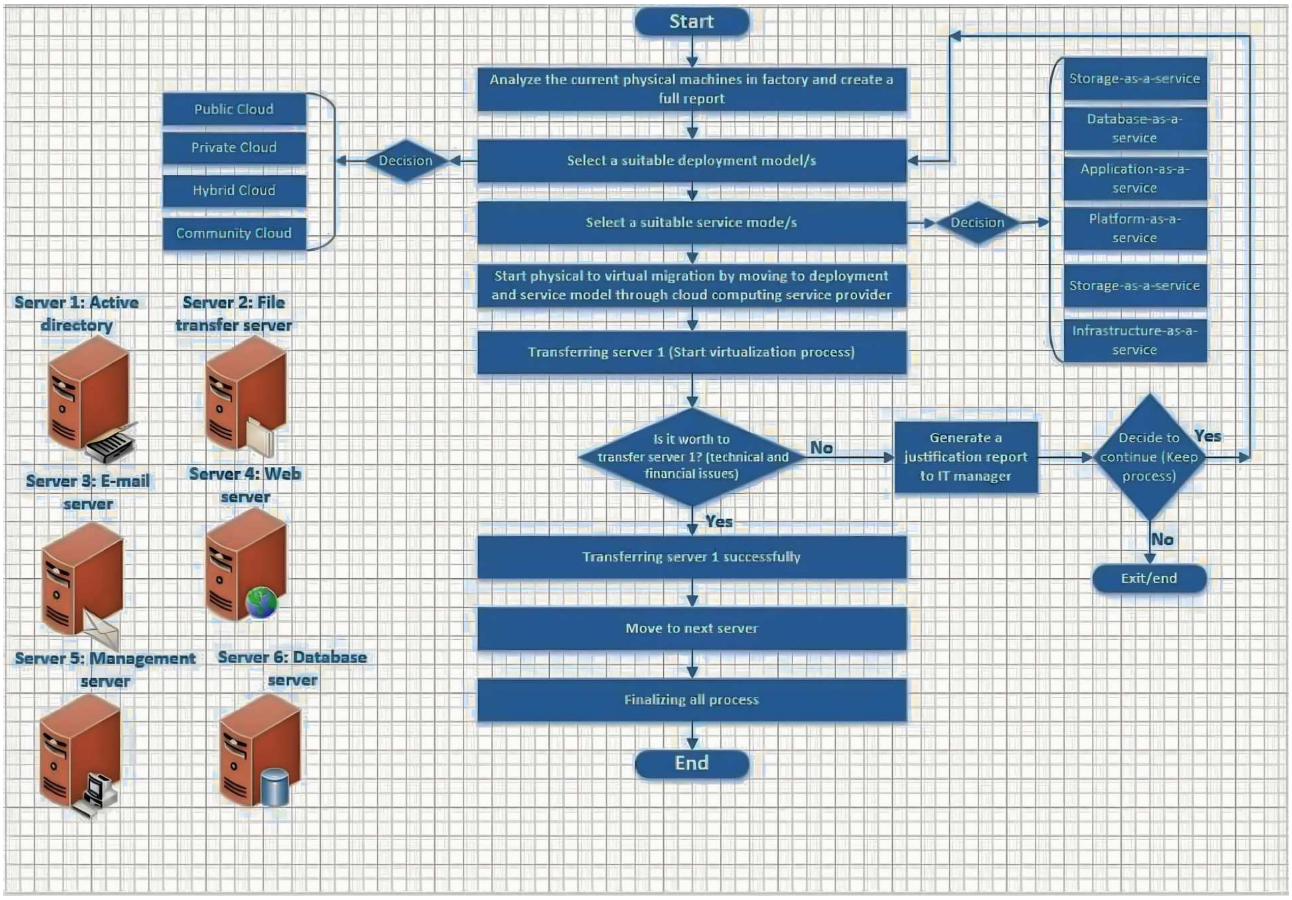

Fig. 1: Proposed framework for transferring data from physical to virtual machines

Table 1: Participant's codes, job description, and years of experience

Participant code	Job description	Years of experience
A1	Senior technical support engineer	8
A2	Technical support engineer	2
A3	IT manager	11
A4	Chief technical office	14
A5	IT manager	10
A6	General manager	18
A7	Financial executive officer	14
A8	Senior technical engineer	9
A9	IT manager	13

6 Main Findings and Proposed Framework

The data for this study were collected through nine interviews, two focus groups, and secondary sources across three different manufacturing sites between February and May 2018. Some interviews were rescheduled or canceled due to participants' other commitments. Data analysis followed the three-stage process outlined by Miles and Huberman, which involves data condensation, data display, and drawing or verifying conclusions. The key findings were visually presented using Microsoft Visio. Factors affecting the transition from physical to virtual machines in Jordanian manufacturing include the cost and availability of virtualization solutions, existing hardware infrastructure, the party responsible for migration, and other related considerations. The research revealed that most respondents reported a lack of resources to support virtualization in their facilities, suggesting a need for a potential solution to facilitate this process.

Respondent A2 highlighted that the main challenge is initiating the virtualization process. Thus, any proposed strategy should be straightforward and easy to implement. The focus should be on simplifying processes, as there is insufficient time to manage complex structures or methodologies. Previous attempts to implement solutions had to be abandoned due to their complexity. Another participant, A7, emphasized the need for a clear and easy-to-calculate solution due to their role in evaluating the financial feasibility of projects. They requested a straightforward and transparent response regarding costs related to the information systems, suggesting that current technology should be utilized where possible.

Table 2: Focus group taking part in this study

Group #	Department	Number of participants
1	Information system	6
2	Information system and management	7

From A7's perspective, the costs and benefits of virtualization are critical in deciding whether to adopt cloud computing. Assessing the return on investment (ROI) for this approach, especially in the short to medium term, is essential. Respondent A5 noted that while initial cloud computing costs might be low due to the absence of physical servers, ongoing maintenance costs remain a concern. Insufficient availability of skilled technical personnel is another challenge during the transition to cloud computing. Secondary sources indicated that most technical engineers had less than three years of experience. One focus group member expressed concerns about job stability and the complexities of implementing virtualization, fearing it could be a difficult transition.

The researcher analyzed the data and developed a guideline for transitioning to virtual machines. Participants from the selected facilities, including A1, A3, and A9, were involved in designing and validating the proposed solution. This solution was tested extensively within the firm's server room, with stages recorded and illustrated using Microsoft Visio. After modifications, the proposed solution was validated for effectiveness by the participants. The recommended virtualization framework is depicted in 1.

As illustrated in 1, the initial stage of virtualization involved a comprehensive evaluation of the physical assets, including the core infrastructure comprising six main servers. Each server serves a distinct role in the company's IT ecosystem: 1. Active Directory Server: This server is crucial for managing user accounts and authentication. It stores all user credentials and permissions, ensuring secure access to the company's network resources. 2. File Transfer and Storage Server: Responsible for handling the transfer and storage of large files, this server facilitates seamless communication and data exchange across various devices within the organization. 3. Exchange Servers (Mail Servers): These servers manage the company's email services, including sending, receiving, and storing emails. They are vital for internal and external communication. 4. Web Server: This server supports the company's website, managing all web traffic and ensuring that the company's online presence is accessible to users around the clock. 5. SQL and Management Server: This server contains essential databases and files related to employees, clients, and operational data. It is integral for managing and accessing critical business information. Evaluation Metrics: Comprehensive reports detail each server's specifications, including: - CPU: Processing power and performance capabilities. - RAM: Memory capacity and its effect on handling multiple tasks. - Hard Drive Capacity: Storage space available for files and applications. - Data Storage Amounts: The volume of data stored and its significance for business operations. Next Steps: 1. Deployment Plan Selection: Based on the evaluation, the next step involves selecting the most suitable deployment plan and service model for virtualization. This decision will be guided by the specific needs and capacity requirements of each server. 2. Migration to Virtual Cloud Servers: Specialized software will be utilized to migrate the existing physical servers to virtual cloud servers. This process involves converting physical hardware resources into virtualized counterparts in a cloud environment. 3. Review and Decision: Once migration is underway, the IT manager will review all financial and technical reports. The decision-making process includes: - Completing the Conversion: If the migration is successful and meets all requirements. - Restarting the Process: If there are issues or if optimization is required. - Cancelling the Project: If the migration proves unfeasible or does not align with business objectives. This process ensures that the transition to virtual servers is efficient and aligns with the company's strategic goals for improved performance and resource management.

7 Conclusion

An increasing number of businesses across various industries have adopted cloud computing services. This research focused on the underutilization of cloud computing in industrial facilities in Jordan. Both positive and negative aspects of cloud virtualization were considered. Data for the study were collected from four factories, including interviews with participants, focus groups, and annual reports. The research adhered to the procedures outlined by Miles and Huberman, which include data condensation, data presentation, and result verification. The study concluded with a data-driven proposal aimed at enhancing virtualization, and the proposed approach has been validated by both the author and the study subjects.

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