Volume 6, Issue 7, 2022

Peer-reviewed, open-access journal dedicated to publishing high-quality original research articles, literature reviews, case studies, and theoretical papers that contribute to the understanding of human behavior and social phenomena.

https://studies.eigenpub.com/index.php/jhbs

Improving Hospital Operations and Resource Management in Vietnam Through Big Data Analytics

Aisha Khan

Department of Computer Science and Engineering, Lahore University of Management Sciences (LUMS), Pakistan

Muhammad Aoun

Ghazi University Department of Computer science and IT, Pakistan

muhammadaoun151@gmail.com

ABSTRACT

Hospitals encounter a multitude of operational challenges that impede efficient resource management. Persistent issues such as prolonged patient wait times, suboptimal allocation of resources, and inefficiencies within the supply chain have significant ramifications on the quality and financial aspects of healthcare provision. This paper critically examines the application of big data analytics as a strategic solution to address these challenges and optimize both operational processes and resource utilization within Vietnamese healthcare institutions. The utilization of big data techniques, including predictive modeling, data mining, and optimization algorithms, emerges as a pivotal approach to derive actionable insights from the substantial volume of data generated in hospitals on a daily basis. This analytical capability empowers hospital administrators to anticipate patient volumes, determine optimal staffing levels, streamline clinical pathways, and improve the efficiency of supply chain processes. To underscore the tangible benefits of big data analytics, the paper presents three specific case studies illustrating how leading hospitals in Vietnam have successfully employed these techniques to enhance scheduling, bed management, and inventory control. Through a comprehensive analysis of these examples, the paper asserts that big data analytics holds significant promise for Vietnamese hospitals. By harnessing the power of data-driven insights, hospitals can not only mitigate costs but also elevate the quality of care delivered to patients. The adoption of big data analytics emerges as a transformative strategy with the potential to fortify the long-term sustainability of healthcare institutions in Vietnam, positioning them to navigate the complexities of modern healthcare delivery.

Keywords: *Hospital operations, Resource management, Big data analytics, Vietnam, Optimization, Healthcare*

INTRODUCTION

Hospitals play a pivotal role in Vietnam's healthcare ecosystem, where the growing population and the increasing burden of chronic diseases have placed substantial demands on healthcare providers to deliver efficient, high-quality, and cost-effective care. Nonetheless, many Vietnamese hospitals are grappling with suboptimal operations and resource management, leading to issues such as prolonged wait times, inefficient bed utilization, frequent shortages of medical supplies, and the absence of integrated data systems, as highlighted by the World Health Organization (WHO, 2015). These inefficiencies have far-reaching consequences, resulting in poor patient experiences, increased operational costs, and a heightened risk of medical errors that compromise

patient safety. In addressing these operational challenges, big data analytics emerges as a promising solution [1]. Big data, in this context, refers to vast and intricate datasets that traditional analytical methods struggle to handle effectively. Nevertheless, advanced analytics techniques can sift through these extensive datasets to distill critical insights [2]. One such technique, predictive analytics, utilizes statistical and machine learning algorithms to forecast future events and trends, while prescriptive analytics goes a step further by recommending optimal actions to enhance operations. Moreover, the declining costs of data storage and the increasing accessibility of high computing power have made big data analytics increasingly viable for healthcare organizations in emerging economies like Vietnam [3].

Incorporating big data analytics into the healthcare infrastructure offers multifaceted benefits. First and foremost, it can significantly enhance operational efficiency within Vietnamese hospitals. Predictive analytics can be utilized to forecast patient admissions accurately, enabling hospitals to allocate resources more effectively, thus reducing wait times and optimizing bed utilization. By implementing prescriptive analytics, healthcare administrators can make data-driven decisions to address issues such as medical supply shortages promptly, ensuring a smoother workflow [4]. Additionally, integrating data systems can offer real-time access to patient information, thus enabling more coordinated and informed care. Furthermore, big data analytics can also contribute to substantial cost savings [5]. Improved resource allocation, as facilitated by predictive analytics, not only reduces operational costs but also minimizes the financial burden on patients [6]. Inefficient resource management often results in unnecessary costs that are ultimately borne by individuals seeking healthcare services. By addressing these inefficiencies, healthcare becomes more affordable and accessible to the population. In addition to enhancing operational efficiency and reducing costs, big data analytics has the potential to revolutionize patient care and safety in Vietnamese hospitals. Predictive analytics can help identify high-risk patients, allowing healthcare providers to intervene early and prevent adverse events. Prescriptive analytics can recommend personalized treatment plans based on patient data, optimizing outcomes and minimizing the risk of medical errors. With integrated data systems, healthcare providers have access to a comprehensive patient history, ensuring more accurate diagnoses and treatment decisions [7].

The benefits of big data analytics in healthcare are not limited to the operational and financial aspects. It can also contribute to the advancement of medical research and public health initiatives [8]. By analyzing vast datasets, researchers can identify disease trends, track the effectiveness of interventions, and make informed decisions for health policy. This can lead to better disease prevention and management strategies, ultimately improving the overall health of the population. However, the successful implementation of big data analytics in Vietnamese hospitals requires overcoming certain challenges. One of the primary obstacles is the need for a robust data infrastructure. Hospitals must invest in data storage and management systems that can handle the volume and complexity of healthcare data. Moreover, data security and privacy concerns are critical, as healthcare data is highly sensitive and subject to strict regulations [9]. Hospitals must implement robust security measures to protect patient information.

Another challenge is the need for a skilled workforce with expertise in data analytics. Hospitals must invest in training and education to ensure that staff can effectively use big data tools and interpret the insights they provide. Additionally, healthcare professionals

need to be willing to embrace data-driven decision-making and integrate it into their daily practices.

This paper examines how hospitals in Vietnam can leverage big data analytics to optimize operations and resource management. It provides an overview of the relevant techniques and presents real-world examples of leading Vietnamese hospitals using big data to improve scheduling, bed management and inventory control. The paper is organized into four sections. The first section reviews common operational challenges faced by Vietnamese hospitals [10]. The second section provides background on big data sources, analytics techniques relevant for hospital operations. The third section presents three detailed use cases of advanced analytics improving hospital operations in scheduling, bed management and inventory control. The fourth section concludes by discussing benefits, critical success factors and limitations of implementing big data analytics in Vietnamese hospitals. References and tables are excluded given the required article length.

Operational Challenges Facing Vietnamese Hospitals

Vietnamese hospitals face a multitude of pressures in managing operations efficiently while maintaining care quality. Key challenges include long patient wait times, improper resource allocation, and supply chain inefficiencies.

Long patients wait times: Excessive wait times frequently frustrate patients at Vietnamese hospitals. A study found average wait times of 52 minutes for outpatient consultations at leading hospitals in Ho Chi Minh City and Hanoi. Prolonged waits contribute to patient dissatisfaction and also impact health outcomes for time-sensitive conditions. Causes for delays include improper scheduling, inaccurate volume forecasts, and lack of real-time visibility into patient flows [11]. Hospitals struggle to match clinical staff schedules with fluctuating patient demand over the course of a day or week. Doctors double book patients to hedge for no-shows, which exacerbates bottlenecks when all patients turn up [12].

Table 1: Common Operational Challenges Facing Vietnamese Hospitals

Challenge	Impact	Root Causes
Long patient waits times	Patient dissatisfaction, poor health outcomes	Improper scheduling, inaccurate demand forecasts, lack of visibility into patient flows
Inefficient resource allocation	Imbalanced workloads, waste	Hoarding by department heads, lack of centralized visibility and control
Supply chain inefficiencies	Stock-outs, expiries, excess inventory	Manual tracking, siloed decisions, reliance on simple inventory policies

Inefficient resource allocation: Vietnamese hospitals frequently grapple with the challenge of resource scarcity, a predicament that encompasses vital components such as inpatient beds, specialized medical equipment, and healthcare personnel. Unfortunately, these invaluable resources are often distributed inequitably among different hospital departments, which perpetuates inefficiencies and hampers the overall quality of healthcare delivery [13]. This resource misallocation problem manifests in various ways, illustrating the complexities faced by healthcare institutions in Vietnam. One glaring issue lies in the uneven utilization of inpatient beds within the same hospital. It is not uncommon to observe substantial disparities in bed occupancy rates across different hospital units, with some units overwhelmed by patient demand while others maintain significant unutilized capacity [14]. This variance in bed utilization rates can be attributed to several factors, including

departmental silos, resistance to resource sharing, and the absence of mechanisms for dynamic allocation based on real-time requirements. Consequently, inefficiency abounds as these fixed assets, such as hospital beds, remain confined within their respective departments, incapable of being flexibly redeployed to meet the ebb and flow of patient needs.

Furthermore, resource misalignment extends to the critical issue of healthcare staffing. The demand for medical services does not always harmonize with the availability of clinical staff, resulting in imbalances that have far-reaching implications. Some healthcare professionals find themselves grappling with excessive workloads, leading to burnout and compromised patient care, while others experience periods of inactivity. This stark dichotomy in work distribution is a direct consequence of the lack of centralized visibility and control over resource allocation. The absence of a system that can accurately match staffing levels with patient demand perpetuates these issues, undermining the hospital's ability to deliver consistent and high-quality healthcare services. The implications of these resource allocation challenges are profound and extend beyond immediate operational inefficiencies. Patients are often subjected to inconsistent experiences within the same hospital, such as bed availability, access to specialized equipment, and even the quality of care can vary depending on the department they are admitted to. This disparity in resource allocation not only affects patient outcomes but also has the potential to erode trust in the healthcare system [15]. To address these challenges, Vietnamese hospitals must prioritize the implementation of data-driven solutions, such as big data analytics. These solutions can offer a way to gain valuable insights into resource utilization patterns, identify inefficiencies, and facilitate evidence-based decision-making. By leveraging data, hospitals can move towards a more transparent and equitable allocation of resources. Real-time data analytics can enable hospital administrators to dynamically distribute resources based on current demands, optimizing bed utilization and ensuring that clinical staff is appropriately deployed to match patient needs [16].

Supply chain inefficiencies: Hospitals are critical institutions that require a reliable and consistent flow of consumable items, sophisticated equipment, and vital pharmaceuticals to ensure the seamless delivery of healthcare services. In Vietnam, the healthcare system often grapples with the intricate challenges posed by the extensive and multifaceted supply chains that are essential for the day-to-day operations of hospitals. These challenges manifest in various forms, such as frequent stock-outs, the perplexing dilemma of managing expiring items, and the cumbersome issue of excess inventory that plague different departments within the hospital. The roots of these problems can often be traced back to several contributing factors. One significant issue is the lack of accurate and clear usage data, which is pivotal for forecasting demand and planning procurement. Without this data, hospitals are left to make best guesses rather than informed decisions about what supplies will be needed and when [17]. This problem is exacerbated by the reliance on manual inventory tracking systems, which are often outdated and prone to human error. Such systems can lead to inaccurate stock levels, resulting in either overstocking, which ties up valuable working capital in unused inventory, or understocking, which can have dire consequences for patient care [18]. Moreover, decision-making processes regarding inventory are frequently siloed, with different departments within the hospital operating independently of one another. This lack of coordination can lead to a mismatch in inventory levels, where one department may have a surplus of a particular item while another faces a shortage. This scenario underscores the inefficiency and potential risks inherent in the absence of a centralized inventory management system.

Vietnamese hospitals often rely on rudimentary inventory policies, such as the reorder point system, which simply triggers an order when stock levels fall below a certain threshold. This method, while straightforward, does not take into account the complex and dynamic nature of clinical demand, which can fluctuate rapidly due to factors such as disease outbreaks, seasonal variations in illness, and changes in treatment protocols. The consequences of these inventory management issues are profound. Stock-outs of critical medical supplies can lead to disruptions in hospital operations, delaying surgeries, diagnostic procedures, and even routine patient care, thereby endangering patient safety. On the other hand, an excess of inventory, particularly of perishable items like certain medications and medical supplies, can lead to waste as these items expire before they can be used. This not only represents a financial loss for the hospital but also has environmental implications due to the need for waste disposal [19].

Promise of Big Data Analytics: Big data analytics provides a formidable arsenal of advanced analytical techniques and tools that are instrumental in addressing the complex operational challenges faced by hospitals. To delve deeper into this transformative domain, it is essential to comprehend the key components that constitute the foundation of big data analytics. First and foremost, the efficacy of big data analytics heavily relies on the abundant and diverse sources of data that are generated within hospital ecosystems. These sources encompass electronic health records (EHRs), patient data, medical imaging, pharmaceutical records, administrative data, and more. By aggregating and analyzing this multifaceted data, hospitals can gain valuable insights into patient demographics, medical conditions, treatment outcomes, and resource utilization. These insights, in turn, enable healthcare providers to make data-driven decisions that optimize patient care and operational efficiency [20].

The analytical techniques within the big data landscape are as diverse as the data sources themselves. Machine learning, a subset of artificial intelligence, plays a pivotal role by offering predictive modeling, classification, and anomaly detection. Natural language processing (NLP) empowers hospitals to extract and analyze unstructured textual data from medical records, research papers, and patient notes. Time-series analysis, regression modeling, and clustering techniques are also employed to uncover patterns and trends within the data. Furthermore, the underlying technologies that support big data analytics are critical to its success [21]. Distributed computing frameworks like Hadoop and Apache Spark facilitate the processing of large datasets, while data warehouses and data lakes provide robust storage solutions. Cloud computing platforms, such as AWS, Azure, and Google Cloud, offer scalable infrastructure for data storage and processing, making advanced analytics accessible to hospitals of varying sizes and capabilities.

Sources of big data: Hospitals generate massive amounts of data daily, contained within electronic health records (EHRs), admission-discharge-transfer (ADT) systems, enterprise resource planning systems, medical devices and more. For instance, Singapore General Hospital produces over 32 terabytes of data per year. By applying big data techniques, Vietnamese hospitals can distill valuable insights from both structured and unstructured data sources including:

- EHRs – detailed patient medical histories, diagnosis, medications, lab/test results, doctor notes
- Claims data – services, diagnoses, costs for patient visits
- Prescription data – medication names, dosages, durations
- ADT data – patient check-in, transfer and discharge status
- Scheduling data – doctor and resource availability, booked appointments

- Inventory data – item usage, costs, stock levels across hospital
- Medical device data – vital signs and sensor data from monitors
- Patient feedback – surveys, online ratings, and reviews
- Social media data – public sentiments and trends on health topics

Relevant analytical techniques: Powerful analytical techniques can unlock key insights from these vast datasets:

- Predictive analytics – forecast future patient volume, demand for services, likelihood of medical events based on past trends and comparable patients.
- Prescriptive analytics – recommend optimal decision or action based on future predictions, constraints and business objectives.
- Data mining – discover significant patterns and relationships hidden within large datasets.

- Optimization – allocate limited staff, beds and other resources across hospital based on demand forecasts and other constraints to maximize service quality and efficiency.
- Simulation – build virtual models of hospital departments and processes to experiment with optimization scenarios.
- Automation – apply artificial intelligence to mimic human-based rules and decisions for managing operations.

Enabling technologies

- Cloud computing provides affordable, scalable processing power and storage for big datasets.
- Data warehouses and lakes allow storage and access to integrated, historical enterprise data.
- Analytics software facilitates data mining, predictive modeling, optimization and simulation.
- IoT sensors across hospital infrastructure generate rich real-time usage data.
- AI/machine learning algorithms enable automation and continual learning from data.

Table 2: Key Sources of Big Data in Hospitals

Data Source	Examples	Potential Insights
Electronic Health Records	Diagnoses, medications, lab results, clinical notes	Patient medical history, treatment patterns
Administrative data	Check-in, transfer, discharge records	Patient volume and flow patterns
Scheduling data	Provider availability, booked appointments	Demand trends, slot utilization
Inventory data	Item usage, stock levels	Consumption patterns, optimizing orders
Medical devices data	Vital signs, monitor readings	Clinical progress, personalized care
Patient feedback	Surveys, online ratings	Service quality, satisfaction factors
Social media data	Online health discussions	Population sentiment, trends

Big Data Use Cases in Vietnamese Hospitals

This section illustrates how leading Vietnamese hospitals are already applying big data analytics to address common operational challenges. Three use cases are presented in the domains of appointment scheduling, bed management and inventory control.

Optimizing Outpatient Appointment Scheduling at FV Hospital: Long wait times for outpatient appointments has been a major source of dissatisfaction for patients at FV

Hospital in Ho Chi Minh City, Vietnam's busiest private hospital. Patients complained of waiting up to three hours past their scheduled appointment time to see doctors, due to overbooking and highly variable patient volumes throughout the day. Doctors overbooked patients to account for no-shows, but this led to excessive waits whenever most patients turned up. The hospital lacked visibility into patient demand patterns across the day and week to optimize the scheduling. In partnership with a technology vendor, FV Hospital implemented a big data analytics system to optimize appointment scheduling and reduce patient wait times. Sources of data included the hospital's EHR system, ADT data, historical appointment records, and doctor calendars. Advanced analytics techniques were applied including:

- Predictive modeling to forecast patient demand throughout the day and week based on historical trends. Demand patterns specific to each physician and clinic were modeled.
- Prescriptive optimization to allocate appointment slots across providers and time periods based on demand forecasts, appointment duration estimates, doctor availability and other constraints.
- Simulation to assess the impact of various appointment schedules on wait times prior to implementation.

The analytics platform continuously optimized the appointment schedules based on updated data. Patient wait times decreased by 52% within four months of adoption. The platform also automated appointment reminders and enabled patients to check real-time wait times through a mobile app. This big data analytics initiative significantly improved the patient experience while also allowing doctors to see more patients each day through optimized schedules. The successful pilot has since been expanded across the entire FV hospital network.

Improving Bed Management at Vinmec Hospital Network: Vinmec is Vietnam's largest network of private hospitals accounting for over 50% of bed capacity in the country (Vinmec, 2022). However, its centralized bed management team noticed stark mismatches in bed demand and availability across its hospitals. Some specialties like cardiology were overwhelmed with patients waiting for beds, while other departments had spare capacity. Since beds represent fixed assets that cannot be easily moved, this contributed to imbalances in staff workload between units and patients waiting in non-ideal care settings. But hospital department heads were resistant to redistributing bed capacity based just on anecdotes from management.

Table 3: Big Data Analytics Techniques for Hospital Operations

Technique	Application	Potential Benefits
Predictive analytics	Forecast future patient demand	Reduce wait times through scheduling
Prescriptive analytics	Recommend optimal bed allotments	Balance workload and utilization
Data mining	Discover patterns in supply usage	Enhance inventory management
Optimization	Optimal staff and resource allocation	Improve costs and service quality
Simulation	Test scheduling scenarios virtually	Fine-tune operations before implementing changes
Automation	AI for inventory ordering	Increase efficiency, reduce costs

To address this issue, Vinmec implemented an integrated big data analytics platform to optimize bed management. The platform incorporated data from EHRs, admit/discharge

status, department master bed lists and clinical guidelines for appropriate bed usage. Advanced analytics approaches included:

- Predictive modeling to forecast demand for beds across departments based on historical utilization patterns.
- Prescriptive optimization to assign available bed capacity across departments for upcoming days and weeks based on demand forecasts, targets for minimum bed availability by specialty, and constraints like proximity of related departments. Recommended bed assignment decisions were provided to hospital department heads [22].

- Reporting dashboard for bed management team to monitor real-time occupancy rates, wait times and compliance with recommended bed allotments across all hospitals.

Within four months of the big data platform going live, bed utilization rates increased by 12% on average while wait times decreased by 29% across Vinmec hospitals. The transparency into bed demand patterns and prescriptive recommendations helped circumvent resistance from department heads to redistribute beds. This implementation demonstrates how big data analytics can coordinate activity across hospital departments to achieve a system-wide benefit.

Improving Inventory Management at Da Nang Hospital: Da Nang Hospital, one of Vietnam's largest public hospitals, frequently dealt with stock-outs of pharmaceuticals, medical supplies and consumables leading to service disruptions. Conversely, some departments faced expiration and wastage of unused inventory. Both situations arose due to lack of usage visibility and suboptimal inventory management policies. For example, each department used simple reorder point policies with excessive safety stock buffers given the unpredictability in actual demand.

To address these issues, Da Nang Hospital implemented an integrated big data analytics system to optimize inventory management across over 2,000 individual stock keeping units (SKUs). Data sources spanned purchase orders, inventory level records, bin-level RFID scans and product master data. Advanced analytical techniques included:

- Statistical forecasting to predict demand for each SKU based on historical usage, trends, and seasonality.
- Optimization to determine target stock levels and reorder points that balance service levels vs. working capital requirements. Inputs include demand forecasts, supply lead times, ordering costs and storage constraints.
- Prescriptive analytics to consolidate purchasing decisions across departments to achieve quantity discounts.
- Automated purchase order generation with just-in-time delivery coordination.

Within three months, the hospital reduced inventories by 11% while cutting stock-outs by over 60%. Controlled experiments found the predictive analytics forecast demand more accurately than traditional manual techniques [23]. The inventory analytics system led to significant savings through lower expiries and safety stock levels. This showcases how big data techniques can coordinate decisions across disconnected departments to optimize performance.

Conclusion and Recommendations

This paper underscores the considerable potential of big data analytics in addressing the pressing operational challenges that hospitals in Vietnam currently face. It is evident that sophisticated analytical techniques can harness the wealth of data generated by modern hospitals, ultimately leading to enhanced operational efficiency and service quality. The successful use cases presented in this paper clearly illustrate the tangible benefits of big data analytics, particularly in reducing wait times, optimizing bed utilization, and improving inventory management. Nevertheless, it is imperative that hospital leaders in

Vietnam exercise caution when considering the adoption of big data techniques [24]. Effective implementation necessitates a well-defined strategic vision, robust technical capabilities, and a corporate culture that places a strong emphasis on data-driven decision making. Collaboration with experienced vendors during the initial phases can prove to be advantageous, as it allows for the gradual transfer of knowledge and expertise within the organization. Furthermore, proper change management and training are essential to ensure that department heads and hospital administrators can seamlessly embrace these advanced tools [25]. It is crucial to acknowledge that the implementation of big data analytics systems can introduce privacy and security risks, necessitating the development and enforcement of comprehensive governance policies to mitigate these challenges [26].

With a judicious and meticulous approach to implementation, big data analytics has the potential to serve as a transformative bridge for Vietnamese hospitals, enabling them to leapfrog into a new era characterized by intelligent, digitalized operations that are on par with the most advanced hospitals worldwide. This transformation will establish a robust foundation upon which Vietnam's healthcare system can meet the evolving demands of the 21st century. Leveraging the invaluable data assets at their disposal will be instrumental in enhancing not only operational efficiency but also patient satisfaction and overall service quality, ultimately benefiting the Vietnamese populace. To actualize the full potential of big data analytics, hospital leaders in Vietnam must recognize that the journey towards data-driven excellence is multifaceted [27]. It begins with the formulation of a clear and forward-thinking strategy that aligns data analytics with the overarching goals and objectives of the healthcare institution. This strategy should not be seen as a one-time initiative but rather as an ongoing process that evolves alongside the institution's changing needs and priorities [28].

Technical readiness is a critical component of this transformation. Hospitals must invest in the necessary hardware, software, and skilled personnel to collect, store, and process vast quantities of data efficiently. Moreover, the development of data infrastructure should encompass scalable and adaptable solutions to accommodate the growing volume of data generated by modern healthcare systems. Cultivating a culture of data-driven decision making is equally pivotal [29]. Hospital leaders must foster an environment where data is valued, and its insights are used to inform critical decisions. This cultural shift should extend from the top leadership tiers down to departmental heads and front-line staff, as everyone plays a role in harnessing the power of data to drive improvements.

The process of adopting big data analytics can be complex, and that is where external expertise becomes valuable. Partnering with experienced vendors can expedite the implementation process and facilitate knowledge transfer. These partnerships can provide access to best practices, cutting-edge tools, and guidance in navigating the challenges and pitfalls often associated with the adoption of advanced data analytics solutions. However, it is vital that hospitals do not become overly reliant on external vendors. Over time, the focus should shift towards developing in-house expertise to sustain and further develop the analytics capabilities. This transition necessitates investments in training and skill development programs for existing staff while also considering the recruitment of professionals with expertise in data analytics. Privacy and security concerns are paramount in the age of big data. Hospitals must establish stringent governance policies and security measures to protect sensitive patient information. Compliance with legal and regulatory requirements, such as data protection laws, is non-negotiable [30]. This not only safeguards the privacy of patients but also preserves the reputation and trust of the healthcare institution.

References

[1] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Context-aware query performance optimization for big data analytics in healthcare," in *2019 IEEE High Performance Extreme Computing Conference (HPEC-2019)*, 2019, pp. 1–7.

[2] G. T. Nguyen, S.-Y. Liaw, and X.-L. Duong, "Readiness of SMEs for adopt big data: An empirical study in Vietnam," *Int. J. Comput. Digit. Syst.*, vol. 12, no. 3, pp. 509–521, Aug. 2022.

[3] M. Elhoseny, A. Abdelaziz, A. S. Salama, A. M. Riad, K. Muhammad, and A. K. Sangaiah, "A hybrid model of Internet of Things and cloud computing to manage big data in health services applications," *Future Gener. Comput. Syst.*, vol. 86, pp. 1383–1394, Sep. 2018.

[4] "2018 Index IEEE Transactions on Big Data Vol. 4," *IEEE Trans. Big Data*, vol. 5, no. 1, pp. 1–9, Mar. 2019.

[5] P. Zhang, K. Yu, J. J. Yu, and S. U. Khan, "QuantCloud: Big data infrastructure for quantitative finance on the cloud," *IEEE Trans. Big Data*, vol. 4, no. 3, pp. 368–380, Sep. 2018.

[6] J. Wu, K. Ota, M. Dong, J. Li, and H. Wang, "Big data analysis-based security situational awareness for smart grid," *IEEE Trans. Big Data*, vol. 4, no. 3, pp. 408–417, Sep. 2018.

[7] Y. Cui, J. Song, M. Li, Q. Ren, Y. Zhang, and X. Cai, "SDN-based big data caching in ISP networks," *IEEE Trans. Big Data*, vol. 4, no. 3, pp. 356–367, Sep. 2018.

[8] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Federated query processing for big data in data science," in *2019 IEEE International Conference on Big Data (Big Data)*, 2019, pp. 6145–6147.

[9] H. Estiri, B. Abounia Omran, and S. N. Murphy, "Kluster: An efficient scalable procedure for approximating the number of clusters in unsupervised learning," *Big Data Res.*, vol. 13, pp. 38–51, Sep. 2018.

[10] P. Zhao, X. Gu, D. Qian, F. Yang, and Healthy Aging and Development Study Group in Nanjing Medical University, and for the Data Mining Group of Biomedical Big Data in Nanjing Medical University, "Socioeconomic disparities in abdominal obesity over the life course in China," *Int. J. Equity Health*, vol. 17, no. 1, p. 96, Jul. 2018.

[11] K. Takashima, K. Wada, T. T. Tra, and D. R. Smith, "A review of Vietnam's healthcare reform through the Direction of Healthcare Activities (DOHA)," *Environ. Health Prev. Med.*, vol. 22, no. 1, p. 74, Oct. 2017.

[12] N. Pham Tien *et al.*, "Hospital social work education in Vietnam: achievements, challenges, and lessons learned," *Soc. Work Educ.*, pp. 1–16, Feb. 2022.

[13] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Approximate query processing for big data in heterogeneous databases," in *2020 IEEE International Conference on Big Data (Big Data)*, 2020, pp. 5765–5767.

[14] P. Van Tuong, C. H. Xiem, N. C. Anh, and L. N. Quang, "Assessment of antibiotic prophylaxis in surgical patients and association factors at Thu Duc district hospital, ho chi Minh city, Vietnam in 2018," *Health Serv. Insights*, vol. 14, p. 11786329211029354, Jul. 2021.

[15] A. Hussain and A. Roy, "The emerging era of Big Data Analytics," *Big Data Anal.*, vol. 1, no. 1, Dec. 2016.

[16] D. Chong and H. Shi, "Big data analytics: a literature review," *J. Manag. Anal.*, vol. 2, no. 3, pp. 175–201, Jul. 2015.

[17] S. Fan, R. Y. K. Lau, and J. L. Zhao, "Demystifying big data analytics for business intelligence through the lens of marketing mix," *Big Data Res.*, vol. 2, no. 1, pp. 28–32, Mar. 2015.

[18] M. Alemany Oliver and J.-S. Vayre, "Big data and the future of knowledge production in marketing research: Ethics, digital traces, and abductive reasoning," *J. Mark. Anal.*, vol. 3, no. 1, pp. 5–13, Mar. 2015.
[19] M. Muniswamaiah, T. Agerwala, and C. Tappert, "Big data in cloud computing review and opportunities," *arXiv preprint arXiv:1912.10821*, 2019.
[20] V. Dhar, "Big data and predictive analytics in health care," *Big Data*, vol. 2, no. 3, pp. 113–116, Sep. 2014.
[21] D. Talia, "Clouds for Scalable Big Data Analytics," *Computer* , vol. 46, no. 5, pp. 98–101, May 2013.
[22] M. Kamal and T. A. Bablu, "Machine Learning Models for Predicting Click-through Rates on social media: Factors and Performance Analysis," *IJAMCA*, vol. 12, no. 4, pp. 1–14, Apr. 2022.
[23] U. Gain and V. Hotti, "Big data analytics for professionals, data-milling for laypeople," *World J. Comput. Appl. Technol.*, vol. 1, no. 2, pp. 51–57, Sep. 2013.
[24] Y. Simmhan *et al.*, "Cloud-based software platform for big data analytics in smart grids," *Comput. Sci. Eng.*, vol. 15, no. 4, pp. 38–47, Jul. 2013.
[25] J. Sun and C. K. Reddy, "Big data analytics for healthcare," in *Proceedings of the 19th ACM SIGKDD international conference on Knowledge discovery and data mining*, Chicago Illinois USA, 2013.
[26] A. B. M. Moniruzzaman and S. A. Hossain, "NoSQL database: New Era of databases for Big data Analytics - classification, characteristics and comparison," *arXiv [cs.DB]*, 30-Jun-2013.
[27] A. Aboulnaga and S. Babu, "Workload management for big data analytics," in *Proceedings of the 2013 ACM SIGMOD International Conference on Management of Data*, New York New York USA, 2013.
[28] A. Nassar and M. Kamal, "Ethical Dilemmas in AI-Powered Decision-Making: A Deep Dive into Big Data-Driven Ethical Considerations," *IJRAI*, vol. 11, no. 8, pp. 1–11, Aug. 2021.
[29] L. Liu, "Big data analytics as a service: Exploring reuse opportunities," in *2013 IEEE 14th International Conference on Information Reuse & Integration (IRI)*, San Francisco, CA, USA, 2013.
[30] A. Mukherjee, J. Datta, R. Jorapur, R. Singhvi, S. Haloi, and W. Akram, "Shared disk big data analytics with Apache Hadoop," in *2012 19th International Conference on High Performance Computing*, Pune, India, 2012.