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(IJ-01) A New Method for Using Feedback to Improve Team Process Effectiveness

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Intervention Processes for Strategic Planning, Change Management and Training & Development have been commonplace since the 1960s or even earlier. However, recently the escalation of change has reached a fever pitch and being able to adapt quickly has never been more important. Many executives in 2025 believe that having effective teamwork is crucial to the success of their businesses. It is effective teamwork that makes quick adaptation possible.

Using an Intervention Process, organizations can often improve a team's effectiveness. In general, intervention processes only work about 50% of the time. This research proposes a method for taking advantage of feedback so that the process can be accelerated and improved. A new method for using feedback, called Observed Objective Feedback (OOF), will be presented along with support for the approach and an illustration for a specific process example. The example will include a description of the key players involved, a description of the variables that make up the feedback (for this example), plus a description of how they will be used to improve team processes. This study presents a new method for monitoring team process interventions. This tool aims to improve team awareness and ultimately team performance.

INTRODUCTION

Scharmer noticed that sometimes their tools and processes worked for an intervention with clients and sometimes they didn't (Scharmer & Yukelson, 2015). Upon looking into this further, he realized that the quality of their results depended on the quality of awareness of those that participated in the intervention. This led to my notion that if awareness could be increased during the intervention, it might be possible to transform an ineffective intervention into an effective one. This means that a method for using feedback to improve team processes might be able to facilitate that team and enable it to be productive.

BACKGROUND

Some type of qualitative technique is needed. A number of Observation Methods have been used in the past for various research purposes. They can involve participant observation or non-participant observation, and they can be a result of direct or indirect observation.

(See Table1)

Table 1   Comparison of 4 Main Types of Observations

Type	Participant	Direct	Indirect	Non-participant
How?	Observing from an insider perspective, as an active participant of a group or organization. It requires full cultural immersion (although only temporarily) while sustaining analytical mindset	Active observing of events unfolding in front of our eyes to record behavior in the environment where it naturally occurs. Usually requires some immersion in the field of study but not necessarily in the culture itself	Research through collecting information, for instance, in the form of videos or written descriptions of events. Also, self-ethnography, remembering events and environments in order to analyze them	Observation from an outsider perspective without interacting with subjects of an observation. The researcher may take the position of an "alien" from a different planet or reality in order to achieve a distance from the well-known
When?	Useful when insider's point of view is important and to gain access to tacit knowledge	In-depth understanding of a social group or an organization but from an external/ independent point of view	Useful when direct observation wasn't possible when the events naturally occurred	Useful when observing a well-known reality, for example, a public place, and there is a need for regarding it from a totally new perspective

(Source: Ciesielska, M.; et al. Chapter 2, p. 43, Observation Methods. *Qualitative Methodologies in Organization Studies. Copyright 2018.*)

Observation Methods are not considered to be scientific methods unless they are carried out systematically using a very structured approach. However, the context of the situation will ultimately determine the way observation can be useful.

Observation Methods are often used in market research. A company called QuestionPro (2025) identified various steps for their Observational Research including: 1) Have a Clear Objective; 2) Get Permission from Participants to watch them; 3) Make sure the observations are unbiased and only "what is seen" is documented, not opinions; 4) Hide Observers so that participants are not aware of them and therefore will not skew their behavior due to being watched; 5) Document the observations; & 6) Use Data Analysis to draw conclusions or confirm a hypothesis. Observations can be done in a natural or a controlled setting, so this must be determined prior to the implementation process.

The biggest problem when using Observation Methods is Researcher Bias because the researcher often conducts the observations and isn't able to separate the actual behavior observed from the view they see through their own filters.

A company called Fuel Cycle (2025) states that Observational Data is appropriate

1) when you need to look at sensitive information and you don't trust participants to be honest in self-reporting; 2) when you need to gain a better understanding about a research question; 3) when it's a new topic and you need to understand participant's behavior better; 4) when behavior in a controlled setting is critical for your research; & 5) when self-reported data might differ from actual actions (even unintentionally). All of these criteria apply for this study regarding team processes.

A lot of research has been done on what it takes for team processes to be effective. Here I will mention some of it, but it's important to note that the studies that have been done are voluminous. Attah, et al (2024) talks about the effectiveness of cross-functional teams, especially for innovation and for technology challenges. Such teams work across silos and are able to accomplish a lot more in a shorter amount of time than more traditional teams

that work within departments. They also talk about the need for leadership and effective communication in order to get the most out of cross-functional teams. They mention that emotional intelligence and conflict resolution are two ways to enhance team dynamics. Finally, they talk about developing teams that have resilience and that are agile and adaptable and able to respond quickly to rapidly changing circumstances.

Moleka (2024) offers a transdisciplinary framework for driving innovation. His approach is transdisciplinary which means that it integrates knowledge, methods, and frameworks from many different academic fields. These include management, psychology, sociology, economics, and technology. Using a synthesis of these diverse perspectives allows for a more comprehensive understanding of the way innovation actually happens. It involves Multilevel Analysis which is at the individual, team, organizational, and eco-system levels. It involves Contextual Embeddedness and acknowledges that contextual factors play a role in shaping innovation. His framework aims to bridge the gap between theory and practice by allowing insights to shape management practices as well as ecosystem-level initiatives. Finally, he's a big believer in collaboration and that interventions can bridge the gap between innovation theory and practice.

Moleka (2024) has identified a number of factors that can be observed to contribute to team process effectiveness, particularly for innovation purposes. However, these factors are also useful for many other types of teams.

Kozlowski & Ilgen (2006) sought to identify promising team processes that influence team effectiveness and that can be shaped by deliberate intervention. They found specific levers that could be applied in a very targeted way for the purpose of improving team functioning.

Their review was quite extensive and many of their findings had substantial support from previous researchers, and some of it even had Meta-analytic levels of support. Meta-analytic support means that numerous studies provided support, essentially "studies of studies" provided evidence for the same factors and levers. Factors included in their study were:

team cognitive processes and structures, team climate, team mental models, team interpersonal, motivational, and affective processes, team cohesion, and team efficacy. Team action and behavioral processes make a difference, particularly when it comes to competence in resolving conflict. Key to the effectiveness of these processes are factors such as coordination, cooperation and communication, as well as individual team member competence.

Leadership was found to be a major leverage point for enhancing team effectiveness. Transformational leadership, which relies on charisma, inspirational motivation and intellectual stimulation, has been found to be especially effective when those leaders provided rewards that correlated with performance.

Kozlowski & Ilgen (2006) identified interventions or levers that shape, influence and align team processes. Each of the levers that they addressed: team design, training and development, and leadership was richly supported by research studies. Their recommendations include: 1) fitting patterns of member capabilities and characteristics together to create a team; 2) creating optimal allocations of resources, responsibilities, and interdependencies across team members; & 3) developing technologies that aid team members in using their resources collaboratively. They also emphasized the value of feedback and situation assessment for adaptation processes.

PROPOSED NEW INTERVENTION

Observed Objective Feedback Method (OOF)

This method was developed in order to avoid problems identified by other researchers. For example, according to Fuel Cycle (2025) researchers often view self-reported research as the Achillie's heal of data collection, because it is not very reliable. The OOF method does not use self-reported data. Additionally, Stephens-Davidowitz (2017) found that participants' perceptions on sensitive topics can even lead to having them lie in order to present a better view of themselves.

Observational research gets around this problem, because it uses other people to do the observing instead of having it be self-reported. It is also important to note that it also does not involve the researcher or facilitator, so that source of bias is also removed from the process. The idea is that those chosen to serve as observers will be in a position to offer the best feedback possible, so that the primary participants can raise their collaboration skills to a higher level-- during the intervention process.

The Observed Objective Feedback Method (OOF) was created to address the job of providing feedback and making improvements in processes involved in the Systems Approach to Modern Management (SAAM) process technique (Taylor, 2025).

(See Figure 1)

Systems Approach to Modern Management (SAMM):
Systems Thinking, Leadership & Teamwork, & Analytical Techniques
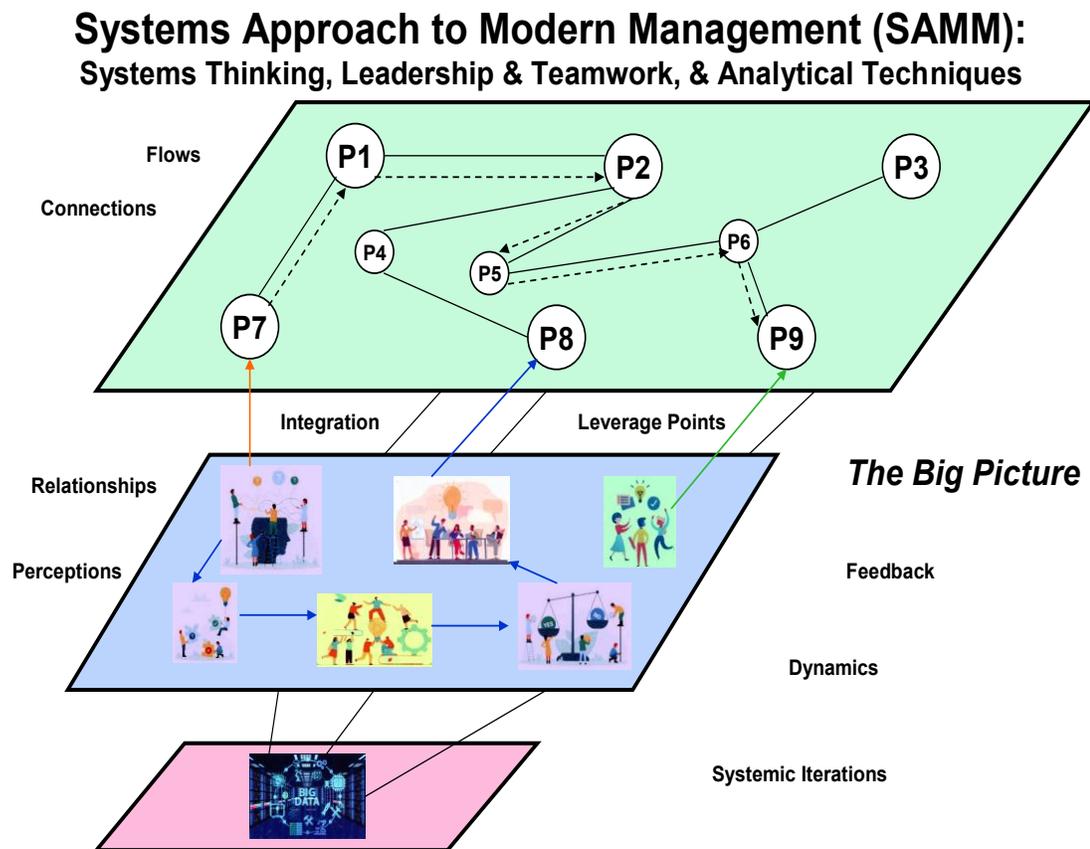
Figure 1   (Source: Includes Google Images-See Refs, Dr. Julia Taylor, Copyright 2024)

This process involves several different collaboration methods including Rich Pictures and Systemigram Mapping. The process involves iterative versions of Rich Picture creation and Systemigram Map creation, which are teamwork exercises. This feedback method (OOF) further enhances the efficacy of SAMM. Each version of teamwork exercises can be improved by taking feedback into account and using it to make improvements.

Although OOF was designed with SAMM in mind, it is important to note that it can be applied to any team process where feedback is likely to improve the outcome. These include processes for goal setting, planning, problem solving, training or even implementing a new project such as incorporating new technology or switching to different technology due to an innovation breakthrough.

This method is advantageous because it takes advantage of the objectivity of specially designated observers who are there to observe the key participants and offer them feedback, so that they can improve their process of working together. Dedicated observers are much more likely to be able to be objective than the actual primary participants. In addition, they are able to devote more of their attention to the task (of observation) than the primary participants would be able to do. (See Figure 2)

Overview of How the "OOF" Method Works

Figure 2

INCREASED AWARENESS
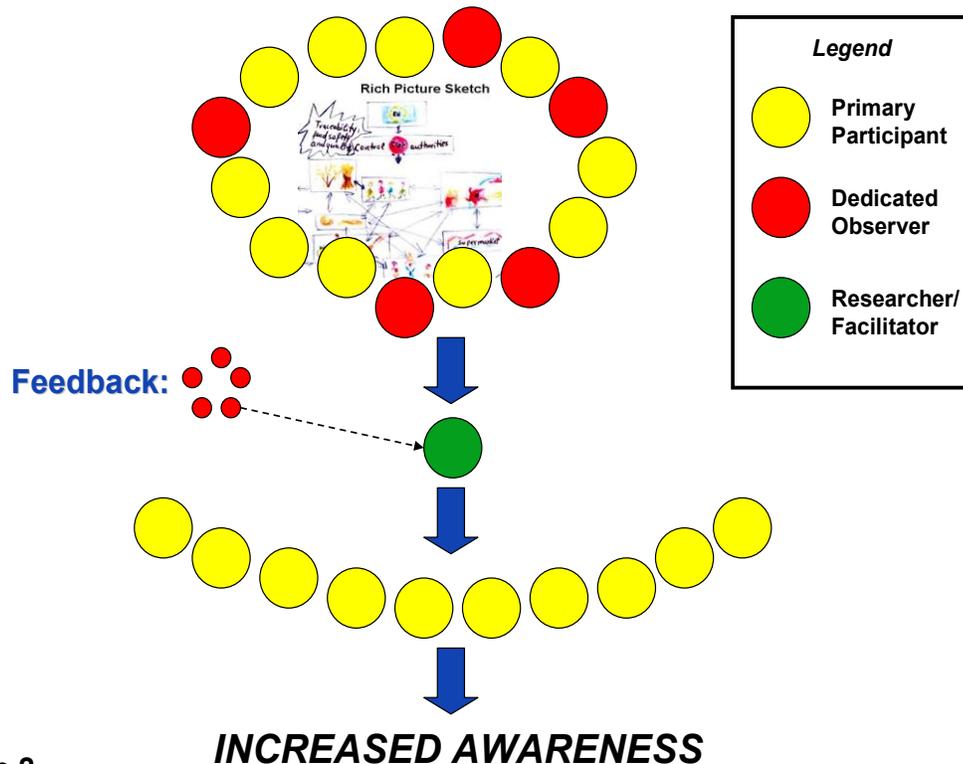
(Source: Dr. Julia Taylor, Copyright 2025)

The way it works is by adding designated observers to the group of collaborators who are participating in the SAAM process. They will appear to the original participants as additional collaborators who are just joining the group. However, they will try to conceal their true role so that the real collaborators are not aware that they are being observed and will therefore be able to behave as they normally would during their collaboration.

Several researchers from recent years have identified factors that make a difference in team processes (Moleka, 2024; Badriyah, et al 2024; & Attah, et al 2024). (See Figure 3)

Inspired Factors (Currently Have Limited Support)

Explore New Possibilities
Experiment with Novel Ideas
Persist in the Face of Uncertainty
Intrinsically Driven to Explore, Experiment, & Create
Psychological Safety
Task Interdependence
Knowledge Sharing
Establish a Framework for Resolving Disagreements
Identify Underlying Causes of Conflict
Voice Dissenting Views without Fear of Negative Consequences
Present Alternative Viewpoints & Consider Each Viewpont
Engage in Creative Problem-Solving
Conflicts Viewed as Opportunities for Growth
Integration within Teams
Working Interdependently to Tackle Complex, Ill-defined Problems
Evidence of Designing Team Structures, Processes, & Leadership for Innovation

Figure 3

(Source:Moleka, Pitshou. September 9, 2024. Attah, R., et al, December 2024. Badriyah, N., et al, April 2024, Copyright 2024)

Figure 3 shows a list of these inspired factors. These factors may make a dramatic difference in team outcomes, but there is currently very little or only limited research that supports them.

Kozlowski & Ilgen (2006) have compiled a research review which consists of "studies of studies" to substantiate their team factors, and in fact most of these factors are supported by Meta-analytic studies. (See Figure 4) Figure 4 shows each factor and its corresponding type of support.

Substantiated Factors (Have Substantial Support)

Team Design & Goal Setting (Holistic Approach)   Meta-analytic Support
Positive Team Climate (Integration of Diverse Perspectives)   Body of Knowledge (theory, methods, & research)
Shared Experience of Team Mental Model Body of Knowledge (theory, methods, & research)
Group Seems to Know "Who Knows What"   Body of Knowledge (theory, methods, & research)
Shared Experience & Team Cohesion   Body of Knowledge & Meta-analytic Support
Leadership in Action with Team Response Body of Knowledge & Meta-analytic Support
Transformational Leadership (Inspiring & Motivational)   Meta-analytic Support
Leader-Member Exchange   Meta-analytic Support
Leader-Task & Developmental Functions   Meta-analytic Support
Conflict Management & Interpersonal Skills **(Transform Conflict Dynamics)** Meta-analytic Support
Evidence of Coordination, Cooperation & Communication Meta-analytic Support
Demonstrated Competencies of Participants Meta-analytic Support
Demonstrated Team Flexibiity, Dynamics & Adaptation Meta-analytic Support

Figure 4

(Source: Kozlowski, Steve W. J. & Ilgen, Daniel R. Copyright 2006)

The designated observers for the OOF process will each have specific factors from these two lists that they look for during the SAMM process or whatever other teamwork process is taking place. In addition, they will document their findings about how well the primary participants are doing on those factors by using open ended input to support their views. These factors are used because they were identified as factors that contribute to creative, innovative, successful collaborations that result in useful outcomes.

An example of the Designated Observer role is shown in Figure 5.

Example of Designated Observer Role

*Note: Each of 5 Factors & The Action Observed by the Primary Participants that Demonstrate that Factor

Explore New Possibilities-- Participant A describes AI Agent that can accomplish a specific goal.

Experiment with Novel Ideas– Participant B & C add in Robotics to solve a shipping problem.

Shared Experience & Team Cohesion– Although Participant B & D talked about the same experience as A & F, they were adversarial towards each other.

Leadership in Action with Team Response– When Participant H presented his idea about rebuilding the Production Department, other team members agreed that this would improve their capability.

Demonstrated Competencies of Participants– All participants displayed competence in their discipline except for E & G. They may need to be prompted to get their input heard.
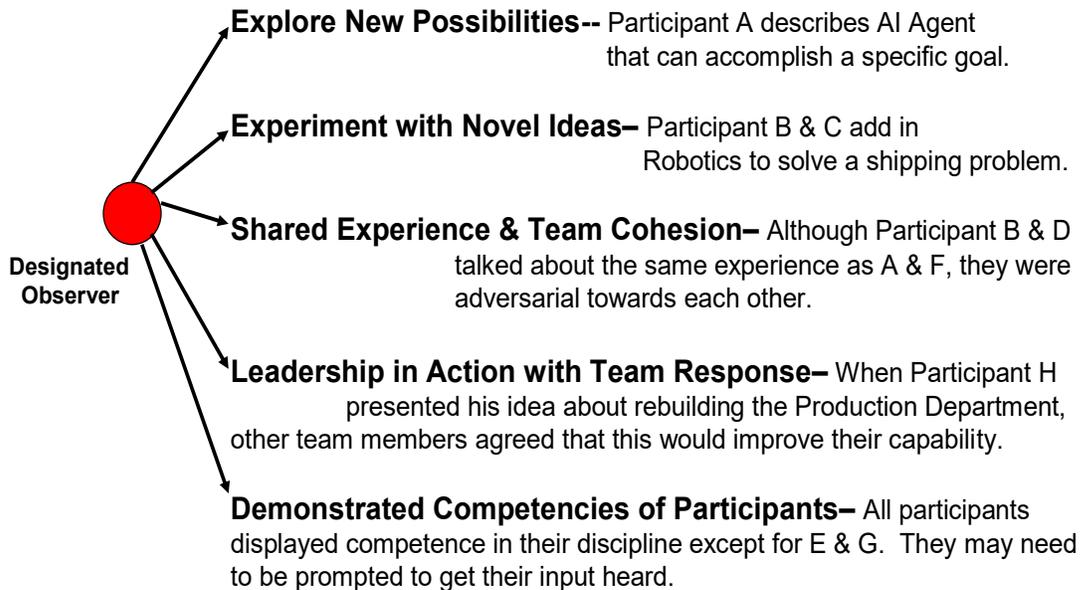
Designated Observer

Figure 5

(Source: Dr. Julia Taylor, Copyright 2025)

As you see here, each observer will have a limited number of factors to observe during the team process. In this example, five factors were selected (from Figure 3 & Figure 4) for the observer. The observer is to note (discreetly) what is taking place with the primary participants that might be useful feedback for helping them to improve their teamwork. For instance, in terms of the last factor, "Demonstrated Competencies of Participants", other team members could take a leadership role and prompt the non-participating participants in order to turn them into participating participants.

Once the feedback has been documented by the designated observers, it is then compiled and reviewed by the Researcher/ Facilitator. (See Figure 2) The Researcher then presents the findings to the primary participants (with the designated observers present, so as to

maintain the secrecy about them being the designated observers) so that they can assimilate it and contemplate how to use it to uplift their teamwork. If this is successful, they now have a newfound level of awareness to apply to their work.

Next as Figure 6 shows (See Figure 6), after the participants go through another iteration of their work together, they are able to achieve better collaboration and a better outcome due to the feedback that they have received.

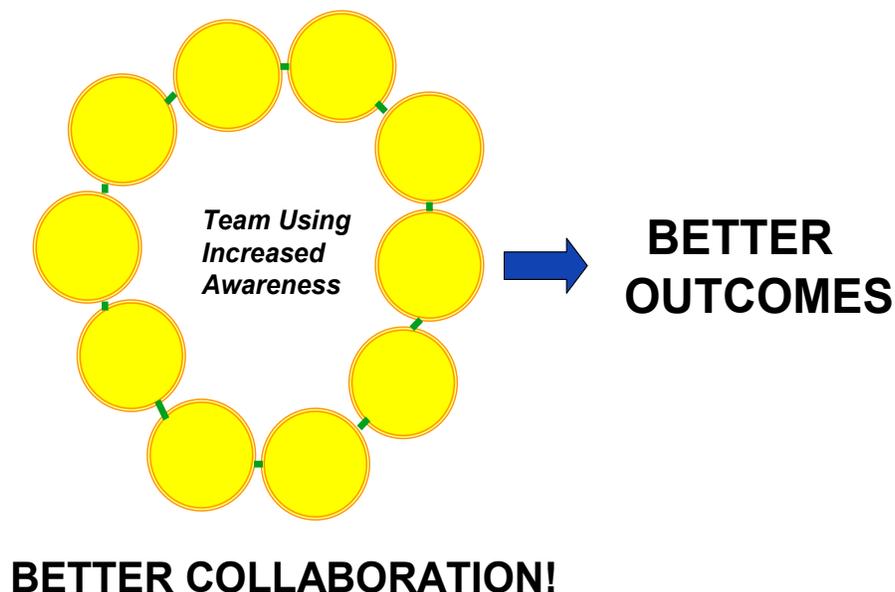**Results of Application of Observed Objective Feedback Method (OOF)**

Team Using Increased Awareness

BETTER OUTCOMES

BETTER COLLABORATION!

Figure 6   (Source: Dr. Julia Taylor, Copyright 2025)

LIMITATIONS OF THE STUDY & FUTURE RESEARCH

The biggest drawback of the study is that it hasn't been tested in the actual circumstances for which it was designed. It is a preliminary, exploratory study with a proposed methodology for using feedback to help teams make immediate improvements during team intervention processes.

Another potential problem is that the "observers" may not turn out to be as unbiased as it is

intended. Even though they are not the primary participants, they still might be biased towards certain outcomes, especially if they are motivated by the desire to look good to their associates. It's important to note that realistically, there isn't any approach in this regard that could be completely bias free, so the best that can be done is to use a system that presents results that contribute to better teamwork. If that is accomplished, then it doesn't matter so much about biases.

Future research could be about refining the approach so that observers can use less open-ended feedback. Using open-ended feedback is necessary initially because we don't know what factors can really make a substantial difference to the team process. However, open-ended feedback is very tedious, difficult to record and difficult to interpret. As an intervention, it may be the best approach, but as research it is much harder to work with.

Eventually, research that is quantitative, instead of just qualitative and antidotal, could possibly lend a lot more credibility to the OOF method. It might also allow interventions to be a lot easier to implement.

CONCLUSION

This paper presents a new method, the Observed Objective Feedback Method (OOF), for improving teamwork and team processes that a team is undertaking. This method builds on previous methods as described in the background section of this paper. It helps a team to receive rapid, unbiased feedback "during the process of their work together" which enables and empowers them to immediately adapt and raise their level of collaboration to new heights, so that their ultimate outcome is much better than it would be otherwise. It is applicable to many different types of team processes.

A key mechanism that gives this method its vigor is the devotion of the designated observers to the task of observing. Plus the fact that these observers are concealed from the other participants, who think they are just additional participants, allows for unbiased reporting on the factors.

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(IJ-02) A Systematic Literature Review on Energy- Efficient Deep Learning Models on Edge Devices

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ABSTRACT

Energy efficiency is vital for edge devices due to the complex computations required by deep learning. The rapid adoption of intelligent systems has significantly increased energy demand, impacting resource constraints, battery life, and environmental sustainability. With the exponential growth of edge devices across various IoT sectors, optimizing hardware and models is essential to maintain accuracy without compromising energy efficiency. The demand for deep learning has surged, leading to a 300,000-fold increase in computational requirements over six years. The number of IoT devices is projected to reach 29.0 billion by 2027, up from 18.8 billion in 2024.

Index Terms— Deep Learning Models, Energy Efficiency, Edge Devices, IoT Devices, Model Compression,

INTRODUCTION

Energy efficiency is vital for edge devices due to the complex computations required by deep learning. The rapid adoption of intelligent systems has significantly increased energy demand, impacting resource constraints, battery life, and environmental sustainability. With the exponential growth of edge devices across various IoT sectors, optimizing hardware and models is essential to maintain accuracy without compromising energy efficiency. [1] The demand for deep learning has surged, leading to a 300,000-fold increase in computational requirements over six years. The number of IoT devices is projected to reach 29.0 billion by 2027, up from 18.8 billion in 2024. [2] This paper will explore the advancements in energy-efficient deep learning for edge devices and aspects of current applications and techniques of edge computing. [3]

This literature review aims to delve into the emerging advancements of energy-efficient deep learning and edge computing while also researching current techniques, applications, and challenges. Over the past few years, significant research has advanced regarding deep learning techniques and methods focused on fostering sustainability while reducing energy consumption. This paper will begin with an overview of the use of deep learning in edge computing and relevant applications like object and anomaly detection, which use real-time processing. [4] Then, in Section 3, we will explore energy-efficient deep-learning techniques, including model compression methods such as pruning, quantization, and knowledge distillation, and then move to lightweight neural network architectures and their design concerning efficiency and accuracy. Specifically, we will perform a comparative analysis of MobileNet, SqueezeNet, and EfficientNet and the tradeoffs between the accuracy and efficiency of early exit architectures and dynamic neural networks. For EfficientNet, we will evaluate the optimization of models through a neural architecture search. [3] In Section 4, we will examine multiple algorithmic optimization techniques like sparse

representation, low-rank factorization, federated learning, and attention mechanisms. [5] In Section 5, we will move to hardware optimization by exploring specialized edge-specific hardware and tailoring models for GPUs. A major aspect of the hardware is embedded batteries and techniques to improve energy consumption to extend operation seamlessly. [6] In Section 6, this paper will critically analyze the applications through multiple large sectors and the IoT market as well as the challenges between energy efficiency, accuracy, and latency. This review will continue to summarize emerging trends and future models that address the energy efficiency challenges in edge computing. [7]

BACKGROUND

Energy efficiency is crucial for the technological, environmental, and economic viability of AI implementation across various sectors. To address resource constraints caused by intensive computing, such as limited power supply from embedded batteries or energy harvesting systems in edge devices, as well as hardware limitations in computational power and memory, we can implement energy-efficient algorithms. [2] These energy-efficient models can extend operation without interruptions in real-time processing or recharging due to the increased energy consumption of deep learning algorithms. This will allow for the scalability of the IoT market and reduce the environmental impact by decreasing greenhouse gas emissions, lowering operational costs, and battery degradation. Energy-efficient models will maintain continuous operation for reliability purposes, which is essential in multiple sectors of edge devices. [8] The widescale deployment is relevant in sectors like health technology, autonomous vehicles, smart cities, space and defense, and renewable energy systems. Figure 1 below describe this flow of general principles of Green Edge AI. [3]
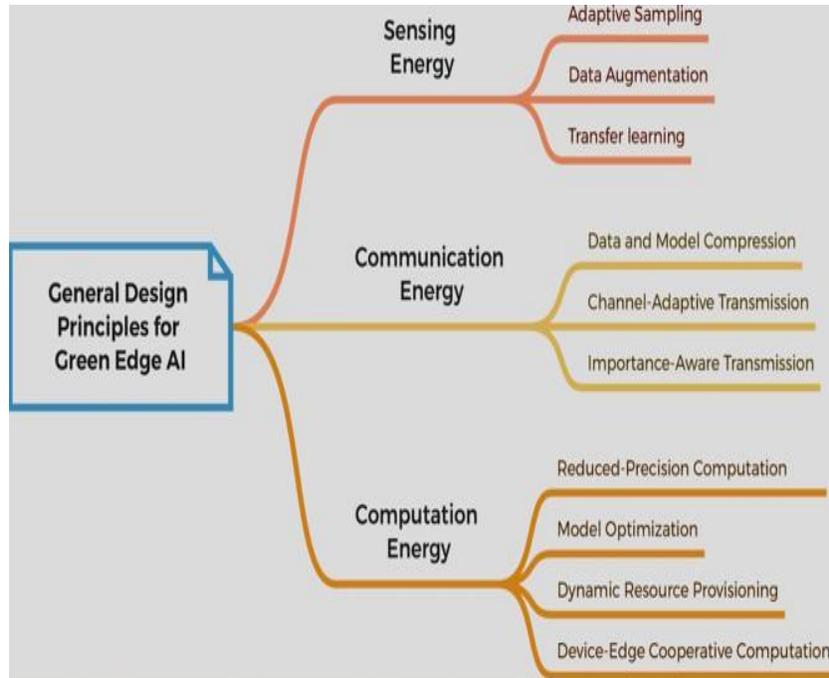
Fig. 1: General Principles of Green Edge AI

ENERGY-EFFICIENT DEEP LEARNING TECHNIQUES

Enhancing the energy efficiency of deep learning in edge computing relies heavily on algorithmic techniques. Deep learning demands substantial computational power and training, making the deployment of model compression methods and lightweight neural network architectures crucial for reducing energy consumption and storage requirements. A main facet of deep learning is object detection by localizing the objects, classifying objects, and identifying objects in image processing. [9] The implementation of deep learning has vastly improved image and speech processing for IoT devices by providing high-accuracy models and low latency. This AI technique is integral in a multitude of fields and researching efficiency is essential for future contributions in these fields and for discovering new advancements. The types of images using deep learning in edge devices include remote sensing, SAR, aerial imagery, and underwater imagery, which are small objects with device constraints and low detection accuracy. [10] Then we see digital images, X-rays, and MRI scans which have higher accuracy models and image classification and object detection. We

also look at istopathological and microscopic images that rely on the use of Generative adversarial networks (GANs) and preprocessing overhead. The relevant domains for classification using deep learning in edge computing include health technology and medicine, autonomous vehicles and transportation, space and defense, agriculture, and smart city development. [4]

Model Compression Methods

Model compression techniques create more compact networks by reducing the size and computational load of deep learning models without sacrificing accuracy. Common approaches to enhancing efficiency include pruning, quantization, knowledge distillation, low-rank factorization, neural architecture search (NAS), and adaptive inference. [10]

1. Pruning

Pruning a deep neural network (DNN) involves removing the redundant connection of neurons in a neural network to improve network performance while maintaining the same standard of network accuracy. There are multiple types of pruning, such as structured pruning, channel pruning, and unstructured pruning. Structured pruning eliminates entire filters from multiple layers to reduce model size. Structured pruning can remove entire units of connections, including channels, filters, or neurons, which allows for hardware efficiency. [11] Chanel pruning is a specific type of structured pruning where entire corresponding channels are removed and new advancements in convolutional neural networks propose acceleration methods so the removal of filters will not have a higher influence. Unstructured pruning eliminated individual weights based on magnitude, allowing a higher compression with sparse matrix operations. [9] There is a 90% weight reduction for pruned ResNet models for image classification with negligible loss of accuracy as seen in Figure 2. [7] Larger, highly compressed models can require retraining to recover accuracy. This technique reduces the number of operations and significantly lessens energy consumption during inference. Regarding efficiency, pruning is better for larger models with redundant

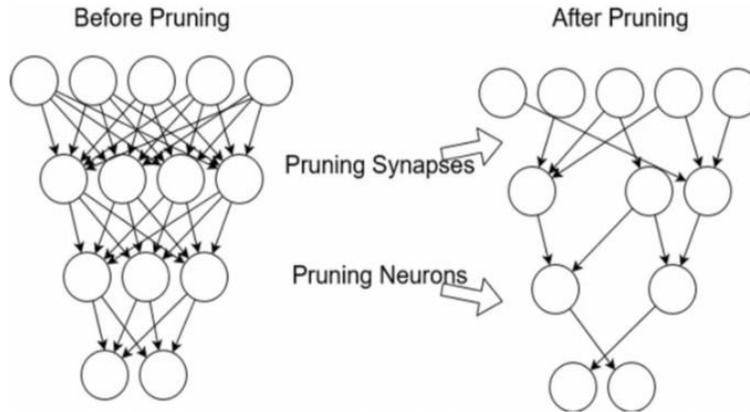parameters, and its latency is improved on edge devices that support spare computation. [11]

Fig. 1: Example of Pruning Process

2. Quantization

Quantization is a model compression method to reduce the size by storing weights in different formats. This lowers the precision of the weights from 32-bit floating-point (FP32) to lower-bit formats, such as 16-bit (FP16) or 8-bit integers (INT8). [10] There are two types of quantization: post-training quantization (PQT) and quantization-aware training (QAT). Post- training quantization will quantize the model after training, while quantization-aware training has higher accuracy retention by integrating quantization during the training process. This model compression method will reduce bandwidth requirements, and computational costs, and increase efficiency because integer operations consume less power than floating-point operations. In both post- training Quantization and Quantization-Aware Training there is up to a 4-time reduction in model size. For efficient quantization in edge devices, we can provide a framework through TensorFlow Lite or PyTorch Mobile for real-time image classification of mobile devices.

[12] The limitations of quantization include a risk of accuracy loss for models that have a high sensitivity to numerical precision, and this method requires hardware that supports

integer computations such as Tensor Processing Units and Edge TPUs. Tensor Processing Units are developed for large-scale matrix computations and Edge TPUs are utilized for edge devices with a limited power consumption. This method is more effective for edge devices with integer computation abilities and latency is reduced on the compatible hardware. [10]

3. Knowledge Distillation

Knowledge distillation is an efficient model compression technique for training neural networks. This method trains a smaller "student" model to replicate and learn the predictions of a larger, thus more accurate, "teacher" model. This process is fully automated compared to quantization and pruning. This model has a lot of energy advantages since the smaller models will be computationally inexpensive compared to the larger, complex networks reducing energy consumption during inference. The "student" model will be faster and smaller while continuing to maintain the accuracy of its "teacher model" without requiring the use of additional specialized hardware. [13] There are many current advancements in knowledge distillation including collaborative learning where multiple "students" can simultaneously learn through the use of "teacher-assistant" models. This method can incur additional computational costs during training based on the depth of the "teacher-student" setup. The most important factor for this compression method is the quality of the "teacher" model since this will heavily affect the performance of the student model. [14] An application of knowledge distillation is deploying compact Natural Language Processing (NLP) like DistilBERT for in edge devices by placing the NLP in a live environment for real application of mobile text processing. The most efficient use of knowledge distillation is when the "teacher" model is readily available with depth and latency is minimal because the "student" model is compressed. [13]

4. Neural Architecture Search (NAS)

Neural Architecture Search is a machine learning technique that automatically uses

algorithms with the ideal combination of layers, filters, and connections to identify the optimal model architecture based on set parameters. This process is fully automated to create specifically designed architectures for energy efficiency operation on edge devices. The NAS models are extremely accurate and are optimized for memory usage and computational output compared to human- designed models. Examples of NAS we will explore are MobileNet, SqueezeNet, and EfficientNet, which are all higher performing than their generic counterparts designed with the same defined parameters. [15] Neural Architecture Search initially has expensive computational requirements during the search phase and requires significant resources for initial training. The efficiency is extremely high when designing models for IoT devices and there is low-latency interference. [5]

5. Adaptive Inference

The final model compression technique we will overview is adaptive inference, where the computational complexity of a model is adjusted based on the input data. This model is effective because it works based on the idea that inputs will not require a consistent amount of power to reach their prediction. This works well for variable workloads because the simpler inputs can bypass deeper model layers and then reduce latency for the simple data. An application of adaptive inference is in the environmental and agriculture sectors, where real-time video analytics and edge AI systems are often utilized. [16] This model has a risk of compromising accuracy for the complex inputs that require full model processing, given the complexities of designing the dynamic architectures. The efficiency is high for real- time applications in edge devices with varied input complexities, and the latency is highly optimized. Table 1, seen below, depicts a comparative analysis of the model compression techniques.

Method	Compression Ratio	Accuracy	Inference Latency
Pruning	High	Moderate to High	Moderate
Quantization	High	Moderate to High	Very Low
Knowledge Distillation	Moderate	Moderate to High	Very Low
NAS	High	Very High	Low
Adaptive Inference	Variable	High	Very Low

Table 1. Comparative analysis of model compression methods.

The advancements to enhance energy efficiency and reduce computational complexity through model compression methods for deep learning models on edge devices vary based on the model parameters. Pruning and quantization are effective for rapid compression and high-speed inference for energy-constrained edge devices. Knowledge distillation is highly accurate for small models in text and speech. Neural Architecture Search has a high initial demand for computational resources but will provide an optimized network based on the given constrained parameters. [5] Adaptive inference is highly efficient for variable input complexity with an extremely low latency. To further the deployment of these compression techniques, new research demonstrates the effectiveness of maintaining accuracy while reducing model size by creating a network in which knowledge distillation and pruned models are used in conjunction. [8]

Neural Network Architectures

There are multiple lightweight neural network architectures designed for edge devices to drive efficiency and performance by reducing the number of parameters and computational power required. These neural architectures effectively utilize resources to minimize consumption for accurate image and object detection and recognition. The three deep-learning models we will examine are MobileNet, SqueezeNet, and EfficientNet, which are

all specifically designed for edge devices. The lightweight models balance performance and accuracy with the challenges and memory and power constraints of edge devices and their hardware. [17] A key model is MobileNet which uses depth-wise separable convolutions to reduce the number of floating- point operations (FLOPs). This lowers the number of parameters to adjust to achieve a five-time reduction in cost compared to the standard CNNs where the convolution is applied to all M channels. The lower amount of computation reduced overfitting, making this highly energy-efficient for mobile and IoT devices. [14] MobileNet has a lower accuracy at approximately 72% top-1 accuracy which is acceptable for edge applications. For real-time applications like object detection and facial recognition, MobileNet demonstrates low latency, balancing out the accuracy compared to larger models. SqueezeNet archives an extremely energy-efficient for memory- constrained devices as it requires 50x fewer parameters than the standard CNN, AlexNet, with the same level of accuracy. SqueezeNet uses fire modules, with a combination of 1x1 and 3x3 filters, to reduce model size. This network has the same level of accuracy as AlexNet but is less accurate than MobileNet or EfficientNet, which it makes up for with its lightweight design, allowing a very low latency idea for edge applications with quick response times. Another popular lightweight neural network architecture is EfficientNet. This model uses a compound scaling factor to scale the models' depth, width, and resolution to optimize computational resources and energy usage. This makes it much more efficient than general CNNs for edge deployment because the constant ratioed architecture reduces unnecessary computation. The smallest variant, EfficientNetB0, has a higher accuracy than MobileNet with approximately 77% top-1 accuracy with a similar efficiency. EfficientNet also lowers the number of floating-point operations compared to MobileNet. [17] The latency for this model is higher than MobileNet due to the complex architecture, but the optimized energy efficiency and accuracy balance this drawback. Table 2, seen below, depicts a

Table 2. Comparative analysis of neural network architectures.

Model	Energy Efficiency	Accuracy	Latency
MobileNet	High	Moderate	Very Low
EfficientNet	Moderate- High	High	Moderate
SqueezeNet	Very High	Low- Moderate	Very Low

Adaptive Models

Combining dynamic neural networks like early-exit architectures with model compression techniques like pruning or quantization is a promising approach for high accuracy and computational efficiency in edge computing. Through this, we can amplify efficiency gains and minimize trade-offs for real-world applications. This method adapts its computations based on the complexity of inputs and given constraints. [17]

1. Early-Exit Architecture

Early-exit architecture allows a network to "exit" sooner when the intermediate layers produce confident predictions and will allow the neural network to terminate computation sooner. This will increase efficiency rather than waiting for all layers to compute when rapid response Is required. Within the model, there are intermediate exit points in the inference process after specific layers. At one of these specific layers, if the output meets a certain threshold, the computation is completed, and more complex inputs will continue to process through deeper layers. [18] This is essential for real-time, low-power applications in IoT and mobile devices and will achieve faster inference times. Early exit architecture has less accuracy if the early exit occurs too quickly when the confidence threshold is incorrectly completed or if too many inputs exit early. This design is complex and will require additional processing of inputs to evaluate confidence at exit points creating a larger model.

Current applications of early exit architecture are BranchyNet and Multi-Scale DenseNet. BranchyNet is popular for image classification tasks with a high level of energy reduction and Multi-Scale DenseNet is used for processing simpler inputs without compromising complex model accuracy as it is designed for real-time inference. [16]

2. Dynamic Neural Networks

Dynamic neural networks adjust their computation based on input as well through three key approaches: dynamic layer skipping, dynamic width networks, and dynamic depth networks. Dynamic layer skipping skips unnecessary layers for simpler inputs by deciding which layers to activate based on the inputs. Dynamic width networks scale the number of active neurons by only activating a subset of neurons during inference to allow model compression based on resource constraints. Lastly, dynamic depth networks adjust depth without predefined exit points, which will quickly change model complexity. [19] Adaptive computation time in recurrent neural networks optimizes inference speed for simple inputs and maintains performance for complex ones, adjusting to hardware limitations. This dynamic model uses sophisticated mechanisms for decision-making but has high implementation costs and can lead to inaccuracies due to lack of predefined exit points. [6]

ALGORITHMIC OPTIMIZATION TECHNIQUES

Optimizing algorithms is vital for creating energy-efficient deep learning models on edge devices. Recent advancements combine methods to improve efficiency for complex tasks. This section covers three techniques for edge devices: sparse representations, low-rank factorization, and federated learning. [20]

Sparse Representations

Sparse representation models reduce computation and memory usage by storing only nonzero values based on the idea that most neural network weights will not compromise performance at zero. This allows for optimized energy consumption with a reduced number of computations through multiple approaches, including algorithms like weight pruning,

using ReLU to increase sparsity in activations where only a specific subset of neurons will be activated, and finding sparse sub-networks that are trained which will theoretically perform as well as a newly trained model. This is observed with Sparse BERT maintaining accuracy with a 40% reduction in omputational cost as dense BERT. [21] This is effective for both convolutional and recurrent neural network models and will have low storage needs because of the sparsity in weights. High levels of sparsity without retraining will potentially comprise accuracy and will require specialized hardware like GPUs optimized for sparse matrices. [22]

Low-Rank Factorization

Low-rank factorization approximates the weights of matrices A with m x n dimensions in neural networks and reduces the number of parameters by identifying redundancies using low-rank matrix decomposition. This method effectively compresses models by up to 50% and works best with fully connected layers to provide a high level of accuracy retention. [23] A common application of low-rank factorization is with speech recognition and image classification models in bioinformatics. This method requires advanced optimization techniques and is less effective for convolutional layers. The efficiency of this method is not as high as pruning and quantization and the latency improves with models that have heavy dense-layer dependencies.

Federated and Transfer Learning

Federated learning eliminates the constant energy-intensive communication with the cloud by allowing training models across multiple edge devices. This reduces the need to transfer data to a central server when training models while only transferring gradient updates that are made during this process to the cloud to minimize the loss function. This is important to scale efficiently across millions of edge devices, maintain privacy by retaining data on devices, mitigate risks associated with data transfer, and lower overall overhead for updates. [24] Federated learning can complicate training due to non-identical distribution across

devices and will increase computational demand on edge devices during local training. Similarly, transfer learning uses pre-trained models across edge devices for specific tasks. This will decrease the use of computational resources during training for higher efficiency.

HARDWARE ACCELERATORS

Edge-Specific Hardware

Edge-specific hardware reduces energy requirements through its tailored design, focusing on inference to minimize unnecessary computations and power usage from training. This hardware supports quantization and performs computations using lower precision, such as INT8, with pre-optimized libraries to minimize energy consumption when deploying models across edge devices. This integrated framework is used in the NVIDIA Jetson Nano, a small AI accelerator designed for edge computing with a GPU based on NVIDIA's Maxwell architecture. The framework supports TensorFlow, PyTorch, and ONNX, which are used for myriad IoT applications. [25], [26] Another popular hardware accelerator designed for inference tasks is Google Coral, which is built around the Edge TPU. This has the highest impact on medical imaging and environmental monitoring as it delivers up to 4 trillion operations per second at 2 watts. Google Coral runs models quantized to 8-bit integers and is ideal for battery-powered IoT devices. Lastly, edge TPUs are specialized to perform inferencing on low-power devices with high accuracy for matrix multiplication operations essential for deep-learning computations. We can further this through algorithm-hardware co-design between the deep learning algorithms and hardware to create a custom, highly optimized design. This will allow hardware architectures to work in conjunction with specific algorithms eliminating redundant operation, memory limitations, and increasing scalability. [27]

APPLICATION CHALLENGES AND FUTURE ADVANCEMENTS

Deep learning for edge devices has the potential to revolutionize various sectors. One of the most significant areas of improvement is health technology and medical applications. AI

edge devices can process X-rays, CT scans, and MRIs on-site to detect diseases in real-time using Convolutional Neural Networks. [8] Recurrent Neural Networks can be used in patient monitoring systems for time-series data. Wearables with deep learning capabilities can analyze vital signs to detect abnormalities for faster response time and early detection. Co-design hardware like NVIDIA Jetson Nano will accelerate real-time medical imaging processing at healthcare facilities by increasing efficiency and reducing power. Another sector that is highly impacted by edge devices is autonomous vehicles for real-time decision-making systems like object detection, lane tracking, and collision avoidance. [2] EfficientNet can optimize accuracy and latency in visual tasks like lane detection or increase traffic flow by dynamically adjusting signals based on current traffic data. Agriculture can deploy MobileNets to analyze drone and satellite imagery to monitor crop health as well as irrigation based on analysis of weather and soil data from Google Coral EdgeTPU with IoT sensors. [11] There is an unlimited amount of potential for deep learning for edge devices in every major sector. This will work towards managing the numerous challenges due to the constraints of devices, complexity of deep learning models, and the need for real-time processing.

CONCLUSION

In this literature review, Energy-Efficient Deep Learning Techniques, Algorithmic Optimization Techniques, and Hardware Accelerators for Energy Efficiency were analyzed for implementation in major sectors. MobileNet has high energy efficiency with low latency for real-time applications with lower accuracy compared to EfficientNet. SqueezeNet has high energy efficiency and low latency with lower accuracy compared to both MobileNet and EfficientNet. EfficientNet has higher accuracy than SqueezeNet and MobileNet with a higher latency due to complexity. Application of early-exit architectures are image classification and speech recognition for the space and defense sectors or mobile use. Applications for dynamic neural networks are object detection and time-series analysis for health technology and autonomous vehicles. These approaches represent the cutting edge of sustainable edge computing, making them essential for applications ranging from autonomous vehicles to environmental monitoring and healthcare.

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(IJ-03) Exploring Common and Emerging Project Management Methodologies

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ABSTRACT

This paper explores traditional and emerging project management methodologies, including Agile, Hybrid, Kanban, Lean, Scrum, Waterfall, Critical Chain Project Management (CCPM), Extreme Programming (XP), Adaptive Project Management (APM), and PRiSM. It compares their principles, strengths, limitations, and use cases across industries. The analysis highlights which methodologies best suit dynamic, regulated, or sustainability-driven environments. It concludes with implementation challenges and tailored recommendations based on project characteristics, emphasizing the need for organizations to align methodology selection with strategic goals.

INTRODUCTION

Project management methodologies are the structured practices, principles, and processes that guide the planning, execution, and completion of projects. As organizations face

increasingly complex challenges, the need for effective and adaptive project management has grown. Traditional models like Waterfall prioritize linear progress, while modern methodologies like Agile and Scrum emphasize adaptability and iterative development. Additionally, sustainability and environmental concerns have given rise to models such as PRiSM, while innovation and uncertainty have necessitated approaches like Adaptive Project Management (APM). This paper provides a comparative analysis of six well-established project management methodologies and four emerging models to support organizations in selecting suitable approaches.

Project management decisions are critical to project success. According to PMI's Pulse of the Profession (2021) report, organizations that align their projects with strategic objectives and use appropriate methodologies are 38% more likely to succeed. The selection of an appropriate methodology can affect not only schedule and budget but also product quality, stakeholder satisfaction, and adaptability to change. Organizations must examine a broader range of management models with increasing globalization, remote collaboration, and stakeholder scrutiny of ESG factors. This paper aims to help project managers make informed choices by highlighting differences and complementarities across established and emerging methodologies.

Moreover, the rapid adoption of digital transformation, AI, and automation in various sectors underscores the need for flexible project frameworks. The COVID-19 pandemic further challenged traditional methodologies, compelling organizations to reassess their approaches and integrate models capable of handling disruption. Consequently, comparative insights into project management methodologies are more relevant than ever to navigating modern complexities.

RESEARCH METHODOLOGY

This research utilizes a comparative literature review approach. Academic journal articles, industry publications, and foundational texts were reviewed to extract data on each project

management methodology. Sources include peer-reviewed journals, white papers, and standards from professional bodies such as PMI. Key characteristics of each methodology were identified: origin, principles, strengths, limitations, practical applications, and implementation challenges. Comparative tables were developed to synthesize findings. The review emphasizes current scholarly perspectives, practical case studies, and expert insights published between 2017 and 2025.

Data were also analyzed for sector-specific usage, frequency of adoption, and project outcomes. Scholarly databases such as JSTOR, ScienceDirect, and Google Scholar were used to find supporting literature. Frameworks were compared using criteria such as flexibility, risk management, cost control, time efficiency, customer involvement, sustainability integration, and ease of implementation. This systematic review ensures a holistic understanding of each methodology in real-world scenarios.

Additionally, a cross-model matrix was developed to identify patterns of overlap, divergence, and complementarity among the methodologies. The review was supplemented by a thematic analysis of case studies and implementation reports from diverse industries, including healthcare, software development, construction, and manufacturing. The triangulation of academic sources, practitioner insights, and industry reports provides robust support for the conclusions drawn.

OVERVIEW OF COMMON PROJECT MANAGEMENT METHODOLOGIES

Agile

Agile emerged in response to the limitations of traditional software development models (Beck et al., 2001). The Agile Manifesto introduced principles prioritizing individuals, working software, customer collaboration, and responsiveness to change. Agile emphasizes iterative development through short sprints, continuous feedback, and collaboration. Frameworks like Scrum and Kanban operationalize Agile principles in distinct ways. Agile is popular in startups and environments where customer requirements evolve quickly.

Agile promotes self-organizing teams and prioritizes adaptability over rigid planning. Tools like user stories, burndown charts, and product backlogs help ensure progress transparency. Studies show Agile increases team satisfaction, customer engagement, and reduces time-to-market for deliverables (Dingsøyr et al., 2023). However, it may struggle in highly regulated or fixed-scope environments.

Hybrid

Hybrid project management combines aspects of Agile, Waterfall, and other methodologies. It is tailored to a project's unique needs, allowing structured planning with iterative execution (Boogaard, 2024). Hybrid methodologies are particularly valuable in large-scale enterprise projects requiring customization and flexibility (Conforto, 2024). Project managers can switch between predictive and adaptive models based on phase-specific needs.

Hybrid frameworks are increasingly used in sectors like construction, healthcare IT, and public infrastructure, where compliance and innovation are needed. They allow organizations to maintain documentation and process control while testing solutions through Agile techniques. Success depends on the project manager's skill in balancing conflicting demands and integrating team feedback loops.

Kanban

Initially developed by Toyota, Kanban is a visual project management approach focusing on workflow optimization. It uses Kanban boards to limit work-in-progress (WIP) and ensure efficient flow through clearly defined stages (Bhaskar, 2022). Kanban is favored in environments requiring continuous delivery and transparency. Its simplicity and visual nature make it accessible to cross-functional teams.

Key principles include limiting WIP, managing flow, and continuous improvement (Kaizen). Kanban facilitates real-time problem detection, increases visibility, and supports lean thinking. It is used widely in IT operations, maintenance teams, and service centers.

However, Kanban may be insufficient for projects requiring rigid deadlines or detailed scheduling.

Lean

Lean project management emphasizes waste reduction and maximizing customer value (Asana, 2025). Based on Toyota's production system, it has been applied to healthcare, logistics, and finance. Lean employs principles like value stream mapping, flow efficiency, and continuous improvement. Lean encourages constant reflection and feedback to identify inefficiencies.

Lean promotes respect for people and empowers teams to innovate processes from the ground up. It includes tools like the 5S methodology, root cause analysis, and visual management boards. Despite its efficiency benefits, Lean implementation may face resistance due to cultural inertia, as well as initial training and change management investment.

Scrum

Scrum, a subset of Agile, features time-boxed development cycles called sprints, supported by roles such as Scrum Master and Product Owner (Schwaber & Sutherland, 2020). It emphasizes team autonomy, regular reviews, and adaptability, making it ideal for dynamic projects. Frequent stand-ups and retrospectives improve communication and foster team ownership.

Scrum's structure promotes accountability and fosters cross-functional collaboration. The Product Owner maintains the product backlog and represents stakeholder interests, while the Scrum Master facilitates the process. Despite its effectiveness, Scrum can be challenging to scale or apply in hierarchical or siloed organizations.

Waterfall

Waterfall is a linear model where each phase (requirements, design, development, testing,

deployment) must be completed sequentially (Royce, 1970). It suits projects with stable requirements and heavy regulatory oversight (Patel et al., 2021). Waterfall is effective for documentation-heavy industries such as defense, pharmaceuticals, and construction.

Waterfall's predictability and clarity of scope make it ideal for high-risk or safety-critical environments. However, its rigidity limits responsiveness to changes. Delays in one phase cascade into the next, and customer feedback is often delayed until the final stages. Project failures under Waterfall often result from incorrect assumptions at the beginning.

OVERVIEW OF EMERGING PROJECT MANAGEMENT METHODOLOGIES

Critical Chain Project Management (CCPM)

CCPM, based on Goldratt's Theory of Constraints, aims to optimize project scheduling by identifying resource dependencies and minimizing multitasking. It uses buffers to protect critical tasks and improve schedule reliability (Anastasiu et al., 2023). CCPM discourages multitasking and promotes resource availability alignment.

Its implementation has resulted in reduced project durations and improved management of uncertainties. Buffers—strategically placed time reserves—absorb variances without affecting project milestones. However, CCPM requires robust planning tools and training, limiting its widespread adoption.

Extreme Programming (XP)

XP is an Agile-based software development methodology focusing on frequent releases, test-driven development, and strong customer involvement (Rojas et al., 2020). Techniques like pair programming and continuous integration enhance code quality and team collaboration. XP is rooted in engineering best practices and encourages customer presence on-site.

XP promotes simplicity in design, small releases, and collective code ownership. It has shown success in reducing technical debt and enhancing stakeholder satisfaction. However,

it requires highly disciplined teams, constant refactoring, and significant customer commitment, which may not be feasible in all contexts.

Adaptive Project Management (APM)

APM supports continuous learning and iterative planning, allowing adjustments as project conditions evolve (Williams & Brown, 2018). It is ideal for innovation-driven projects where requirements are fluid. APM emphasizes stakeholder engagement, rapid feedback, and double-loop learning. It allows goals to evolve in tandem with discoveries and external changes.

APM empowers teams to learn from experience and rapidly adjust strategies. It supports decentralized decision-making and works well in research, education, and climate resilience initiatives. Challenges include maintaining coherence and stakeholder alignment as project parameters shift.

PRiSM (Projects Integrating Sustainable Methods)

Developed by GPM Global, PRiSM integrates ESG (environmental, social, and governance) principles into project planning and execution. It encourages long-term value, lifecycle impact assessment, and sustainability alignment (Katsarelis & Adamopoulou, 2014). PRiSM emphasizes ethical impact, biodiversity, carbon reduction, and resource stewardship.

PRiSM uses tools like the P5 Standard and sustainability indicators to assess impact. It suits infrastructure, urban planning, and renewable energy initiatives. However, the need for specialized training limits adoption, and organizations often prioritize cost and timeline over sustainability unless regulatory frameworks or stakeholder pressures require it.

COMPARATIVE ANALYSIS: FEATURES, STRENGTHS, AND LIMITATIONS

Methodology	Strengths	Limitations	Best Use Cases
Agile	Flexible, fast feedback, innovation	Requires high collaboration	Software, marketing
Hybrid	Customizable, combines best practices	Complex implementation	Enterprise projects
Kanban	Visual tracking, reduced bottlenecks	Less structured	IT operations, service workflows
Lean	Eliminates waste, improves value	Requires cultural shift	Manufacturing, healthcare
Scrum	Structured iterations, team autonomy	Needs experienced teams	App development
Waterfall	Clear milestones, detailed documentation	Rigid, poor adaptability	Government, pharma
CCPM	Optimizes resources, buffer use	High complexity	Manufacturing, construction
XP	High-quality code, early issue detection	Customer involvement burden	Startups, web dev
APM	Continuous learning, high adaptability	Risk of scope creep	R&D, transformation projects
PRiSM	ESG alignment, long-term value	Training needs, slow adoption	Green building, infrastructure

PRACTICAL APPLICATIONS

Agile and Scrum are prevalent in software development and marketing, supporting fast-paced innovation (Dingsøyr et al., 2023). Hybrid combines flexibility and control in large-scale IT or construction projects (Boogaard, 2024). Kanban enhances operational efficiency in support and development teams (Martins, 2025). Lean principles are adopted in manufacturing and healthcare to streamline operations (Asana, 2025).

CCPM is used in construction to reduce delays and manage complex dependencies (Anastasiu et al., 2023). XP supports rapid, high-quality releases in software startups (Rojas et al., 2020). APM is valuable in volatile environments, like tech innovation and environmental restoration (Williams & Brown, 2018). Organizations adopt PRiSM to align projects with sustainability goals (Katsarelis & Adamopoulou, 2014).

IMPLEMENTATION CHALLENGES

Each methodology poses unique challenges. Agile requires team discipline and stakeholder availability. Hybrid needs expert leadership to manage diverse frameworks. Kanban depends on visual clarity and WIP control. Lean mandates cultural shifts that may face internal resistance. Scrum's dependency on experienced team members and frequent reviews can lead to fatigue.

Emerging models present added complexity. CCPM requires buffer management expertise and accurate data. XP's reliance on pair programming and frequent feedback can be resource intensive. APM, while adaptive, risks losing direction in the absence of strong oversight. PRiSM demands knowledge of sustainability standards and may increase upfront costs.

OVERLAPS AND DISTINCTIONS

Agile, Scrum, XP, and APM share iteration, feedback, and adaptability principles. Scrum and XP provide more structure, while APM allows flexibility. Kanban and Lean aim to improve flow and reduce waste, but they differ in structure and application. Waterfall stands apart as the most rigid model. PRiSM is distinct in its focus on environmental and ethical project outcomes. Hybrid methods overlap with all others by design, incorporating multiple strategies.

RECOMMENDATIONS

Project managers should select methodologies aligned with their industry context and project dynamics:

- Use **Agile** for tech-driven, iterative projects.

- Apply **Hybrid** in enterprise settings needing both flexibility and structure.

- Employ **Kanban** for operational workflows needing visual tracking.

- Implement **Lean** in efficiency-focused sectors.

- Opt for **Scrum** when product updates are frequent.

- Choose **Waterfall** for regulatory projects with fixed requirements.

- Adopt **CCPM** in projects needing schedule optimization.

- Use **XP** in development teams needing rapid, reliable outputs.

- Apply **APM** in uncertain, evolving project contexts.

- Utilize **PRiSM** for ESG-aligned and sustainability-focused projects.

CONCLUSION

This paper examined ten project management methodologies. Agile, Scrum, and XP suit fast-paced industries; Waterfall and CCPM serve well in structured environments. Hybrid, APM, and PRiSM address complex, adaptive, or sustainability-oriented needs. This paper concludes that Agile and Scrum are best for innovation-driven teams, while Waterfall remains crucial for structured, regulatory projects. Hybrid and APM offer tailored flexibility but require skilled oversight. PRiSM is best suited for sustainability-focused organizations.

The findings advocate for strategic alignment between project goals and management methodologies. Organizations can improve outcomes by selecting methods that reflect operational complexity, regulatory environment, and stakeholder expectations. The right approach depends on project goals, industry standards, team capabilities, and stakeholder priorities. Organizations can improve project success by aligning methodology with strategic intent and investing in training and adaptation.

FUTURE RESEARCH

Further empirical studies should examine how hybrid models perform in cross-functional or remote environments. Case studies focusing on PRiSM's long-term impact on ESG outcomes would benefit sustainability discourse. Mixed-method research involving interviews, project performance metrics, and longitudinal studies could offer deeper insights into methodological effectiveness.

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(IJ-04) How to Avoid the Top Five Academic Writing Issues in High Education

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ABSTRACT

This researcher identifies the top five writing issues from observing her students from five different universities she served during her past decade. Then, this researcher addresses and discusses how to address those five issues in students from higher educational institutions. At the end of this paper, this researcher concludes her findings and suggests future research recommendations. This paper not only identifies writing issues from students' academic writings, also analyzes reasonable and applicable solutions for how to avoid or conquer them. The impact of this paper is significant because it is a meaningful qualitative research paper based on an adjunct professor's past decade observations and educational industry firsthand experience. The goal of this paper is to share valuable and applicable teaching and grading experiences to benefit future academic writing instructors and bringing better educational experiences for younger generations.

INTRODUCTION

Dr. Junqiao Xiao received her Master of Arts in Teaching in August 2010, Doctor of Education in Educational Leadership and Management in July 2014, Juris Doctor in May 2019, and Doctor of Business Administration with a concentration in information and data science in December 2021. She is an adjunct professor teaching evening or online courses at various universities in addition to being a full-time lawyer. During her decade-long teaching career, she has observed and graded numerous academic papers from undergraduate and graduate students. Thus, she has a strong interest and passion for writing this paper to summarize and conclude the top five issues in academic papers from higher education students.

METHODOLOGY

This is a qualitative research paper based on Dr. Junqiao Xiao's decade-long observation of grading student academic papers from five different universities. Due to the lack of literature reviews on this topic, this paper is entirely based on Dr. Xiao's personal teaching experiences. This research is based on phenomenology and grounded theory of qualitative research. Phenomenology, a qualitative research method derived from existential philosophy, informs data analysis and discloses the essence of human experience (Hasselkus, 1995). Phenomenology seeks to use lived human experience to better understand the essential nature (Hasselkus, 1995). Furthermore, grounded theory explains social processes in complicated practical environments (Bytheway, 2018). Grounded theory is based on observation but requires the elimination of bias (Kriukow, 2021). Thus, this paper is a combination of phenomenology and grounded theory of qualitative research, so there is lack of literature reviews in the academia.

The purpose of this research paper is not only to identify the top five writing issues in higher education academic writings but also to analyze reasonable and applicable solutions for how to avoid and conquer these mistakes. Dr. Xiao divided this paper into five parts to discuss the most common errors students make in their academic papers, including: (1) indirectly

address the academic paper titles, (2) lack of clarity, (3) data collection difficulties, (4) American Psychological Association (APA) format errors, and (5) Artificial Intelligence (AI) misuse or overuse.

Indirectly Address Academic Paper Titles

Among thousands of student papers Dr. Xiao has graded, many students do not directly address their paper titles. Their paper titles point in one direction, but their paper bodies veer off in different directions. In this subsection, Dr. Xiao will discuss three kinds of scenarios involving indirect title justification issues, which include: (1) opinion-based academic papers, (2) concept-related academic papers, and (3) comparison academic papers.

The most common scenario involves academic papers that articulate opinions. To effectively address such papers, students must first identify the title and clearly define the purpose of their writing. Subsequently, they should base their argument on their own research, the surrounding context, pertinent information, and/or current public policy. Scholarly literature reviews, qualitative research findings, and quantitative research data can significantly enhance the quality of these academic papers, provided that the research outcomes and analyses are pertinent to the paper's title. However, students are often "carried away" with discussion and analysis that are no longer relevant to the initial topic. Students should revisit the academic paper's topic, integrating literature reviews, qualitative findings, and quantitative data to reinforce their argument.

The second scenario often arises in academic examinations or conferences, where a specific concept must be addressed in the paper. In such cases, students should apply the relevant concepts and rules to their academic writing. They should utilize literature reviews, qualitative research findings, or quantitative research data to logically connect the elements of the concept with the associated rules. This approach enables a comprehensive explanation of each element of the concept and a deeper elucidation of the concept statements.

The last scenario presents a challenge due to the inherent complexities of writing

comparative study papers. To effectively address this type of paper, students must first identify the comparison ranges and focus on the specific choices to be compared. Subsequently, they should identify relevant literature reviews, qualitative research findings, or quantitative research data for both subjects if the study is a comparison of two subjects. The difficulty level increases significantly when comparing three or more subjects. After identifying the subjects of comparison, students should elucidate their rationale for undertaking comparative study, which may be grounded in academic experiences or public policy considerations. It is essential for students to articulate sentences that highlight the similarities and differences between the choices. Ultimately, they should reaffirm their comparison study choices in the conclusion of the paper.

After successfully addressing the paper title justification, students need to pay attention to the main body writing of the paper. The paper title should be direct to the paper contents. Clarity is the fundamental of academic paper writings.

Lack of Clarity

After establishing the suitable title of the academic paper, students should prioritize the clarity of their writing. The academic paper writer assumes the role of a narrator and is responsible for all writing tasks; thus, students must recognize that the writer is not a participant in the narrative of the academic paper. Adopting an objective perspective is fundamental for crafting a compelling academic paper. At the outset of the writing process, students should read at least ten scholarly journal articles, academic books, or research papers. Following this, they should contemplate the type of academic paper they intend to write and develop a comprehensive outline.

In academic papers for a specific course, the outline should be based on the required rubric. Students must address the required review of literature and focus on course-related topics. They can use simple illustrations and examples to enhance clarity. It is not recommended for students to use three-syllable words if they do not deeply understand their meanings.

Without clarity, the content does not matter. Wydick (1978) asserted that trimming verbose word clusters is key to writing a clear paper. According to Wydick (1978), spotting bad constructions is significant for effective writing.

In academic papers for specific research, the outline should be based on the requirements of the research hypothesis. The objective of the academic paper is significant because it is related to the research hypothesis. The paper should address the research topic thoroughly. A prudent literature review is key to success.

If the academic paper is for an exam only, then the outline should be concentrated on exam points. The paper should be direct and to the point; otherwise, students will lose exam points. Students should use familiar concrete words in their writing because exam graders have limited time to grade the papers. If exam graders cannot understand the paper within a short period of time, there is no way to receive high scores. Students should avoid compound prepositions to make the paper as simple and easy to understand as possible.

Regardless of the type of academic paper students are writing, proofreading aloud is a highly effective method for identifying errors and enhancing clarity. If students encounter difficulties in reading their writing work aloud, various technological resources, such as the "read aloud" function in Microsoft Word, are available to assist. There are so many technology students can use to help them read aloud their papers, so picking up a favorite and useful one is key to write high quality academic papers.

Achieving clarity in academic writing is the baseline objective. Students should leverage technology to aid their learning process rather than allowing these tools to produce the content for them. While Grammarly is useful for identifying spelling errors and catching more grammar mistakes than standard word processors, students must still verify its suggestions. Additionally, students can utilize tools like ChatGPT or other AI resources to outline paper structures, as these tools offer broad perspectives on specific topics. Bibliography generators can also be employed, but students must meticulously review the

generated citations to ensure they conform to the proper APA format.

Thus, after addressing the clarity issues of the academic papers, the next step is to take consideration of data collection of the research. Not all papers contain a data collection section because some papers are purely based on literature reviews. However, successful data collections can increase the professionalism for your papers.

Data Collection Difficulties

From Dr. Junqiao Xiao's observations from her past ten years teaching, many students had difficulties about collecting data for their academic papers, which caused low quality either qualitative research or quantitative research. Dr. Junqiao Xiao wrote two dissertations for her Doctor of Education and Doctor of Business Administration before, from her past experience, there are three applicable ways of data collection, which include: (1) post the survey link into the Facebook or social media survey exchange groups, (2) Email the survey link to friends directly, and (3) send the survey link to friends via social media.

For the first method of posting the survey link into the Facebook or social media survey exchange groups, students must join some survey exchange groups. To identify some survey group names, such as some Facebook survey groups with names like student survey exchange, the research survey exchange group, survey 4 survey, survey exchange, student survey swap, please do my survey, and so on. Some survey groups specific survey years and some specific survey types, such as dissertation. After joining those survey groups, students can post their surveys and wait for others to participate in their surveys and ask them to leave screenshots. Students also can finish others' surveys and reply to the surveys with the survey done screenshots.

From Dr. Junqiao Xiao's observations of around 20 survey groups, the most interesting survey should have four characteristics, which include: interesting research topics, easy understandable subject matters, plain sentences, and less options in choices. Interesting research topics can make participants open the surveys because no one wants to open a

survey with a less attractive topic. Easy understandable subject matters can make people understand the meaning of the research because no one wants to join a hard subject matter. Plain sentences can help participants to understand the concepts well because no one wants to read a survey with long and complicated sentences. Less options in choices can help participants make quicker decisions because no one wants to participate in a survey with so many long choices.

There are many quantitative research tools in the market for students to use, but there are not too many technological choices for qualitative research. Nvivo is one of the great tools for students to use for qualitative research, students can use it for literature reviews or interview transcripts organizations. There are many free instructional videos on YouTube for students to use.

Thus, after collecting enough data and analysis data, we need to discuss how to follow the APA format to write a professional academic paper. In the next section, we will discuss APA format issues. Many students lost points of their papers due to APA format issues, especially in the reference section.

APA Format Issues

After justifying the title and writing the main body of the paper, students need to pay attention to the reference section, where most errors occur. If students use automated web services or AI-related software for the reference section, they must verify the citations and references afterward, as errors may still remain. Some web services or AI-related software may require additional payment; if students do not pay, the software may generate a few correct APA format references and leave the remaining ones in incorrect formats.

Students must follow the APA 7th edition guidelines for their paper, at least until 2025 when this paper is published. Students must keep at least three sentences per paragraph and avoid making paragraphs too long or too short. Additionally, they should maintain consistent formatting throughout the paper. This means not using different formats for the front page,

the abstract page (if it has one), the content page (if it has one), the main body of the paper, the reference page, and exhibits (if there are any). Students should include separate cover and reference pages for their papers. The entire paper, including the reference section, should be double-spaced. There is no need for a running head on the first page of the paper. The page number should be included in the upper right corner of all pages (APA, 2019). For dissertation-level writing, there is no need to include a page number in the upper right corner of the cover page, but students can keep the first page number for regular undergraduate and graduate assignment papers, unless specified otherwise by the university writing manual.

There are also many students who have difficulties with headings of their paper. According to APA (2019), level one heading should be bold in the center of the paper for the paper title or dissertation chapter or identifying the first topic after the introduction, level two heading should be bold in the right side of the paper to identify each subtopic of the section, level three heading should be bold and Italic in the right side to identify a subsection of the second subtopics, level four heading should be bold within the beginning of the paragraph, and level five heading should be bold and Italic within the beginning of the paragraph. However, there are some students confused about the heading's rules, which cause many confusing paper organization, especially misuse of level one and level two headings.

For the reference section, only the most common APA format errors will be discussed. Students only need to capitalize the first word of the journal article title or the book title and capitalize each word of the journal title. Students must italicize the book title, the journal title, and the volume number. Furthermore, students should indent the second and subsequent lines of each reference. Remember that there should be no "retrieved from" wording before the reference website link and no publisher's city and state before the publisher's name (APA, 2019). Only one space should be used after a period at the end of a sentence (APA, 2019). In-text citations should include the author's name and publication year when paraphrasing another author's sentences from their book (APA, 2019). In-text citations are shortened to the first author's last name followed by "et al." before the comma

and publication year (APA, 2019). The DOI link should be a real link, meaning it should take the reader to the correct reference page when clicked (APA, 2019). Students can use the singular "they" for gender-neutral pronouns, without always using "his or her" in their writings (APA, 2019). The age group and participants of surveys should be specific (APA, 2019).

For the appendix section, the appendix page should follow the reference section. Students should maintain consistent formatting throughout the paper, including the appendix sections. Students must leave an empty page that includes only the name of the appendix, with all materials starting on the next page (APA, 2019). The margins on both sides should be consistent with the previous pages, not too wide or too narrow.

Therefore, if students are unsure about their writing or formatting issues, they should use the tutoring services provided by their universities, which can greatly increase the quality of their writing in a short period of time. Consistently using university-provided writing services before submitting paper assignments will provide students with lifelong benefits. However, some students may consider to use AI to help their paper writing or APA format checking, so the last topic will discuss the AI misuse and overuse issues in academic writings.

Artificial Intelligence Misuse or Overuse

From Dr. Xiao's observations about how students use AI for academic writing, some student misuse or overuse AI tools in their academic writings. Some students may argue that they only use AI tools for grammar check and APA format check, not for academic paper contents. However, this argument is weak because AI tools can do more than that. If students can control themselves within the grammar check and APA format check, then the results are happy, but some students want AI tools to write the whole papers for them, which caused additional academic integrity issue. In this situation, some universities attach some AI identification related functions to catch up the use of AI of academic papers when students

submit their papers.

According to Neefischer (2025), AI writings caused originality, creativity, ethics, plagiarism, and fabrication concerns. In addition, Chakravorti (2024) mentioned that AI causes some trust problems, which include supercharged information, security and safety concerns, no transparency, ethics issues, bias, instability, and so on. Thus, when students use some AI tools to aid academic paper writings or paper outlines, such as ChatGPT or DeepSeek, students have to pay attention to the above issues and concerns.

Harker (2023) asserted that some science journals set up some new authorship guidelines for AI generated texts because researchers use AI for scientific writings causes ethical, dependable, and accountability questions. Furthermore, student academic papers have to same concerns of authorship because there are some an-AI software applications in the market to help students get out of the universities' catch up of the AI percentage recognition, which made the professors hard to distinguish the handwriting papers or AI papers.

Some universities or organizations also build AI committees to catch up on AI papers, on the other hand, some universities have some policies to allow students to use AI for paper outlines or grammar checks. For example, Culp (2023) asserted that ChatGPT revealed strong capabilities to help in research design in academia, so more and more researchers use or consider using new technologies to scientific writings. Thus, it is very hard to prohibit students from using AI on academic writings, so some writing rules and requirements may change in the future.

Eke (2023) mentioned that AI generated contents threatened academic integrity, so academia needs to take actionable steps to control this challenge. According to Ugwu et al. (2024), there are some ways to control AI tools in scientific writing, such as human must set up guidelines to ensure AI assists writings and not replace human writings, verify AI generated contents, prohibit crediting AI as co-authors, disclose the usage of AI tools to make sure the transparency, review and updated AI usage polices, and so on. Thus, there

are so many ways universities can control misuse or overuse AI tools in academic writing. Hopefully, we will have better solutions in the future.

CONCLUSION

The above information is based on Dr. Junqiao Xiao's personal opinions and teaching experiences. No identified research studies support her opinions, so please use her techniques and recommendations carefully. This paper is purely for general educational purposes, not for commercial use. The passion of publishing this paper is to collaborate and cooperate resources and knowledge together to help more educators better educate younger generations and grade student papers more effectively. There are some limitations to her research, such as geographic limitations, only a decade of observation, no research funding, lack of literature reviews of this topic, and no additional faculty help. Therefore, all phenomena described in this paper only apply within a limited decade scope of observations. If anyone wants to conduct in-depth research related to this topic, please let the author know.

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(IJ-05) Artificial Intelligence in Higher Education: Opportunities, Challenges, and Future Directions

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ABSTRACT

Artificial intelligence (AI) is transforming higher education by reshaping teaching, learning, and administrative practices. This paper examines the current state of AI adoption in higher education, highlighting both opportunities and challenges. Drawing on literature, case studies, and empirical evidence, it explores how AI applications—such as intelligent tutoring systems, automated grading, chatbots, predictive analytics, and accessibility tools—are being implemented across institutions. Findings suggest that AI offers significant benefits, including personalized learning, efficiency gains, improved accessibility, and data-driven student support. At the same time, serious concerns emerge around academic integrity, algorithmic bias, privacy, faculty preparedness, and equity gaps. The analysis underscores that successful integration of AI requires ethical guidelines, inclusive design, and faculty development, as well as international collaboration to ensure equitable access. The paper concludes that AI is a double-edged sword in higher education: it has the potential to enhance student outcomes and institutional effectiveness, but only if deployed thoughtfully, with pedagogy and ethics at the center.

INTRODUCTION

Artificial intelligence (AI) has rapidly shaped and disrupted higher education (HE) in profound ways- from adaptive learning platforms and intelligent tutoring systems to

automated grading and AI-powered chatbots. This paper examines the scope and impact of AI on academic processes and student outcomes with a focus on both the opportunities it creates and the challenges it presents for faculty and students. The examples and cases presented in the paper come mostly from the U.S. higher education context, however, we tried to bring international trends and examples as appropriate.

The following questions guide the paper: How has AI changed teaching and learning in higher education? What opportunities has it created, and what ethical, pedagogical and accessibility challenges and risks has it posed? What does the future holds for AI technology in university classrooms? These questions are important to answer because universities worldwide are investing in AI technologies.

The paper first reviews the literature on AI in HE, then presents case studies and empirical evidence of specific AI applications. We then synthesize findings to discuss implications, limitations, and future directions.

CURRENT STATE OF AI IN HIGHER EDUCATION

Popenici and Kerr (2017) define AI as "computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction and use of data for complex processing tasks (p. 2)". In higher education, AI encompasses machine learning, natural language processing, and generative models applied to instructional design, assessment, student support, and campus administration (Wang, et al., 2023; Crampton, et. al, 2023).

The recent surge in generative AI (GAI) increased research and application among researchers and instructors. Crompton and Burke's (2023) recent systematic review found that publications nearly tripled in 2021–22, and that China has recently surpassed the U.S. as the most prolific country in AI research. Users in HE predominantly used AI tools for the following tasks: (1) Assessment/Evaluation, (2) Predicting, (3) AI Assistant, (4) Intelligent Tutoring System (ITS), and (5) Managing Student Learning.

There is much debate and disagreement among scholars and practitioners on the impact of AI in HE. Proponents argue that AI will personalize learning at scale, give students on-demand support, and free instructors from routine tasks, thereby enhancing education quality (Gibson, 2024). Skeptics warn of potential pitfalls from academic integrity issues and algorithmic bias to loss of human interaction and equity gaps (Al Zahrani, 2024). Understanding both sides is crucial for policy and practice. Overall, the literature highlights both positive affordances of AI and critical concerns.

Benefits of AI in HE:

A major benefit of using AI in higher education is personalization of education based on personal needs and learning styles. AI systems can tailor instruction and feedback to individual learner profiles. For instance, *intelligent tutoring systems (ITS)* adapt problems to a student's skill level, leading to improved learning gains. Wang et al. (2023) note that ITS have potential to effectively transform teaching and learning especially by adapting to student needs. Adaptive learning tools has been shown to improve student test results by 62%. AI-powered learning analytics can identify at-risk students early and suggest interventions: one recent study using machine learning on student demographic and engagement data predicted dropouts with high accuracy (Matz et al., 2023).

AI can also assist instructors by *automating routine tasks*. Automated essay scoring and feedback tools save grading time and provide consistent feedback; one hypothetical case described how an AI service gave students pedagogical merits of consistent feedback quickly, though it also raised issues of cost and privacy (Kumar, 2023). Furthermore, AI chatbots (e.g. Jill Watson at Georgia Tech) can answer student queries 24/7 without adding to faculty workload. In one classroom trial, a ChatGPT-based assistant improved students' perception of teaching presence and even correlated with higher grades and retention (Design Intelligence Lab)

AI also *promotes accessibility and inclusion*. AI technologies can make learning "more

accessible, equitable, and inclusive" for students with disabilities (Gibson, 2024). Automated captioning, text-to-speech, and intelligent study aids can help learners with visual, hearing, or cognitive impairments access content. For example, AI-driven captioning in video lectures benefits deaf or hard-of-hearing students. Moreover, as one pre-service teacher survey found, a majority (61%) agreed that AI tools could help include students with diverse learning needs (Kalnina, et al, 2024). In summary, proponents argue that AI can extend pedagogical reach (24/7 assistance), improve efficiency (automated grading and analytics), and enable new forms of learning (adaptive tutoring, virtual labs).

Limitations and Challenges:

The literature also identified significant downsides of AI in education. A common theme of concern is *academic integrity*. Many faculty fear generative AI will fuel cheating. A 2024 survey reported 68% of instructors believe AI will significantly harm academic integrity, and nearly half of students admitted it's already easier to cheat with AI tools (Coffey, 2024). Relatedly, the rise of AI-generated content (essays, code, even artwork) undermines traditional assessment methods. Critics warn that *over-reliance on AI* answers can reduce students' own learning: for example, a thematic study cautioned that while chatbots provide valuable support, there is a risk of over-reliance, which may lead to diminished cognitive abilities and authentic learning (Zhai, et al., 2024)

AI systems trained on *biased data* may produce biased recommendations. The Heliyon study by Al-Zahrani (2024) systematically catalogued AI's *"shadows"* in education: concerns include algorithmic bias, erosion of human connection, threats to privacy, and equity gap. For example, a predictive model might unfairly flag students of color as at-risk due to biased historical data. Moreover, there is a digital divide: students and institutions with less access to technology may fall behind. Al-Zahrani notes *"access equity"* as a major concern (that AI tools could widen existing gaps). Indeed, Gibson (2024) points out the irony that students with disabilities may benefit most from AI but are often *"least able to use them,"* and only a tiny fraction of tech developers involve disabled users in design.

Many educators worry that AI could *devalue human roles in teaching*. The OECD emphasizes that we must *"rethink education"* in light of AI's rapid progress. (OECD, 2023). AI can handle routine tasks, but it cannot replace human skills like creativity, empathy, and ethical reasoning. UNESCO-ICHEI likewise stresses that "teaching personnel provide the irreplaceable human skills of embodiment, creativity and ethical reasoning" and should remain at the center of education (UNESCO-ICHEI, 2023). Research on AI in education often invokes the *"human-in-the-loop"* principle: technology should augment rather than supplant instructors. Finally, faculty face practical barriers: surveys indicate many professors feel unprepared to integrate AI, lacking training and administrative support (Mowreader, 2025). Instructors express anxiety about how to use AI tools appropriately, and report needing clear guidelines and professional development.

Academic work on AI in higher ed is expanding rapidly, covering cognitive theories (how AI tutors affect learning) and sociocultural issues (ethics, equity). Researchers have documented that AI can create personalized, data-driven learning but also emphasize the critical need for safeguards. Key themes include adaptive learning (AI tailored instruction), student support (chatbots and analytics), assessment (automated grading), and the socio-ethical dimension (bias, privacy, teacher roles). This review suggests a nuanced picture: AI offers powerful new capabilities for universities, but its adoption must be managed carefully to avoid pitfalls (see Table 1).

Table 1. Summary of Advantages and Disadvantages of AI in Higher Education.

Opportunities (Pros)	Challenges (Cons)
Personalized learning: Adaptive tutoring, immediate feedback tailored to student needs	**Academic integrity:** Tools like ChatGPT make cheating easier
Efficiency: Automated grading/feedback saves instructor time and provides consistent evaluation	**Bias & fairness:** AI may encode and amplify biases in educational outcomes
24/7 student support: Chatbots and virtual TAs answer questions anytime	**Over-reliance:** Students may lose critical thinking if they unquestioningly accept AI outputs
Inclusion: Assistive technologies (captioning, translation, etc.) improve access for diverse learners	**Digital divide:** Not all students/institutions have equal access to AI tools, risking inequity

Data-driven interventions: Learning analytics predict at-risk students for early help	**Privacy concerns:** AI systems often require large student data, raising privacy/security issues

CASE STUDIES: AI APPLICATIONS IN PRACTICE

To better understand how AI is being implemented in higher education, this section presents selected case studies that illustrate both the promise and complexity of AI integration. These examples span instructional support, student services, and administrative functions, offering a grounded view of how AI is reshaping the academic experience.

1. Virtual Teaching Assistants

Georgia Tech's "Jill Watson" is perhaps the most well-known example of an AI teaching assistant. Originally built on IBM Watson and now leveraging ChatGPT, Jill Watson was deployed in an online computer science course to answer student questions in discussion forums. Students were unaware that Jill was an AI until the end of the semester—and many rated her as one of the most helpful TAs. The chatbot was able to respond to frequently asked questions 24/7, reducing the burden on human instructors and improving response times. In one evaluation, the ChatGPT-powered Jill Watson provided more accurate and safer answers than the older rule-based system, increasing teaching presence without extra faculty workload (Taneja, 2024). The developers report that Jill's use of large course documents "intelligent textbooks" allows it to ground answers contextually, reducing hallucinations (ibid). However, limitations remain: for example, Jill's retrieval-augmented generation (RAG) means it can't summarize content longer than its context window, and it may trade off coverage for safety (some answerable questions go unanswered to avoid mistakes). These experiments illustrate both an advantage (scalable student support) and a challenge (ensuring accuracy and transparency).

2. Advising Chatbots

Universities are piloting AI chatbots to facilitate academic advising tasks. Surveys and pilot

tests show that well-designed chatbots can enhance student engagement and autonomy. For instance, a multi-university project called "Advisely" used a GPT-4 based chatbot to guide students on course selection and degree planning. Their findings suggest that Advisely significantly enhanced academic advising process, reduced administrative workload, and improved students' access to accurate information (Abdelhamid et al., 2024). The study found that students feel chatbots help them ask clarifying questions and get immediate feedback on assignments, thereby improving students' self-efficacy, problem-solving skills, and critical thinking. Tailored feedback and personalized learning pathways provided by chatbots have been linked to greater learner autonomy and motivation. On the advisor side, chatbots can alleviate advisors' workload; research highlights that "chatbots can serve as virtual academic advisors", guiding students through course planning and resources, which is especially valuable when faculty and staff are overburdened. However, the same literature cautions about over-reliance: educators must ensure bots complement rather than replace human guidance and remain vigilant about data privacy and fairness. For example, if a chatbot's course recommendations are based on biased data, it could mislead students (Kalnina, 2024).

3. Intelligent Tutoring Systems (ITS)

A large body of research evaluates AI-driven tutors in specific subjects (often STEM or language learning). A meta-analysis by Wang *et al.* (2023) reviewed 40 experimental studies of ITS in real classrooms. It confirmed ITS's *"great potential"* to improve learning but also reported mixed results across contexts. ITS often boost student achievement when well-implemented, but factors like classroom integration and teacher support affect outcomes. For example, the Carnegie Math Cognitive Tutor (used in many universities) has been shown to raise math scores significantly, but only when instructors actively incorporate its feedback into instruction. Similarly, Arizona State University integrated ITS into introductory math and biology courses. These systems adjust problem difficulty in real time based on student performance, offering hints and feedback tailored to individual learning

paths. The results have been promising: ASU reported increased pass rates and reduced withdrawal rates in courses using ITS compared to traditional formats. Wang *et al.* highlight that most studies focus on academic performance; few examine ITS's effects on non-cognitive outcomes (motivation, collaboration) or consider long-term use. (Wang et al, 2023). This suggests further research is needed on the broader impacts of adaptive tutoring.

4. Automated Grading and Feedback

Several universities experiment with AI grading for programming assignments and essays. Initial studies show time savings: an AI grader can process hundreds of student code submissions and return feedback instantaneously. In one U.S. trial, using an AI grader for introductory computer science class increased grading consistency and allowed instructors to focus on difficult cases. However, automated grading is not flawless. Issues with data privacy could prevent faculty from relying on these tools. In addition, an AI grading tool may not be able to assess the subtle aspects of writing quality that a human grader would. Modern language models have shown performance on par with human raters in some assessments, but educators remain concerned about transparency and fairness. Reliance on AI grading may lead to diminished engagement and authentic learning experiences if students' game the system (Zhang, et al, 2024; Zhai, et al., 2024). Thus, many institutions currently use AI grading only as a supplement (e.g. to give students draft feedback) with final assessment still human-verified.

5. Learning Analytics and Predictive Models

Universities increasingly use AI to analyze student data and predict outcomes. For example, a consortium of U.S. colleges partnered with a campus app to collect data on logins, event attendance, and social interactions. An AI model trained on this data predicted first-semester dropout with 78–88% accuracy (Matz et al, 2023). Engagement metrics (e.g. how often a student participated in study groups or campus events) added predictive power beyond grades alone. This enabled early alerts: advisors could reach out to students flagged as "high

risk," offering resources or counseling. Georgia State University reports that their predictive analytics program, with timely interventions, has raised graduation rates and generated millions in additional revenue, illustrating the practical impact of such AI systems (Georgia State has noted that even 1% retention gain is financially significant).

6. Accessibility and Assistive AI

AI tools can greatly assist students with disabilities. For example, AI-driven speech-to-text and text-to-speech enable students with hearing or visual impairments to access lectures and readings. Educause highlights that AI technology tools hold remarkable promise for providing more accessible, equitable, and inclusive learning experiences (Gibson, 2024). The University of Illinois has integrated AI tools to improve accessibility for students with disabilities. Through partnerships with ed-tech companies, the university offers AI-generated captions for lectures, real-time transcription, and personalized learning interfaces that adapt to students' cognitive and sensory needs. Similarly, AI-based translation and voice assistants aid international students and those with learning disorders. However, one must note potential drawbacks: Gibson (2024) points out that ironically, students with disabilities… are often the most disadvantaged or least able to use new AI tools, because of cost or lack of design accessibility. Few AI education products solicit input from people with disabilities during development, raising concerns about usability and representation.

Beyond the U.S., many countries are integrating AI in higher education. For instance, universities in China and Europe are using AI tutors and analytics at scale, often supported by national initiatives. The UNESCO-ICHEI Higher Ed White Paper (2024) calls for multilateral collaboration and policy frameworks to ensure AI enhances "inclusive and equitable" education globally. OECD's Digital Education Outlook (2023) similarly emphasizes "opportunities, guidelines and guardrails" for AI in education. These international efforts reflect a common agenda: leverage AI to improve teaching and learning (aligning with Sustainable Development Goal 4 on education) while safeguarding human values.

IMPLICATIONS, LIMITATIONS, AND FUTURE DIRECTIONS

The integration of AI into higher education presents both exciting possibilities and serious challenges. As the case studies illustrate, AI can enhance learning outcomes, streamline administrative processes, and improve accessibility. However, these benefits are not automatic—they depend on thoughtful implementation, ethical oversight, and continuous evaluation.

1. Implications for Faculty and Students

For faculty, AI offers tools to personalize instruction, automate grading, and identify students in need of support. However, it also requires new competencies: instructors must learn to work alongside AI systems, interpret data outputs, and design assessments that are resistant to AI misuse. Professional development and institutional support will be critical.

For students, AI can provide 24/7 assistance, adaptive learning experiences, and more inclusive environments. Yet, it also introduces risks of over-reliance, surveillance, and inequity. Students need guidance on how to use AI ethically and effectively, and institutions must ensure that AI tools do not reinforce existing disparities.

2. Limitations of Current Research and Practice

Despite the growing body of literature, much of the current research on AI in higher education is exploratory or based on small-scale pilots. There is a need for more longitudinal studies, diverse institutional contexts, and interdisciplinary approaches. Additionally, many AI tools are developed by private companies, raising concerns about transparency, data privacy, and commercialization of education.

Another limitation is the lack of student and faculty voices in AI design. Inclusive co-design processes are essential to ensure that AI tools meet the real needs of diverse learners and educators.

3. Future Directions

These limitations suggest several recommendations for the future trajectory of AI in education:

Ethical AI development: Institutions should adopt clear guidelines for responsible AI use, including fairness, accountability, and transparency. For example, any analytics system should be audited for bias, and students must consent to data usage.

Human-AI collaboration: Rather than replacing educators, AI should augment human teaching by handling routine tasks and enabling deeper engagement. Training programs should develop faculty competencies in AI literacy and adaptive pedagogies.

Equity and access: Universities must address the digital divide and ensure that all students benefit from AI innovations, not just those with the most resources.

Research and evaluation: Ongoing assessment of AI's impact on learning, equity, and well-being is essential to guide policy and practice. The effectiveness of many AI tools is still *"complicated"* and context dependent. Universities should collaborate on research into which AI interventions truly enhance learning outcomes, and under what conditions. Longitudinal studies could track effects on skills development over time. Educational researchers should measure not only academic performance, but also motivation, equity, and social-emotional impact.

Redesign of Curriculum and Assessment: Embrace AI as a subject and tool in curricula. Students should learn about AI (its capabilities and limits) as part of critical digital literacy. Simultaneously, instructors may need to adopt new assessment methods (e.g. in-class projects, oral exams, portfolio work) that value original thinking over rote output. Providing opportunities for students to verify AI outputs can turn a potential cheating device into a learning catalyst (e.g. comparing AI-generated answers to research-based answers to identify errors).

International Collaboration: Higher education stakeholders should share best practices globally. UNESCO and OECD emphasize multilateral cooperation in AI education. Joint frameworks (like the UNESCO-ICHEI White Paper) and shared resources (such as open AI textbooks or open-source tools) can help level the playing field across countries. For example, open AI-powered tutoring systems could be localized for different languages and curricula through international partnerships.

In conclusion, AI in higher education is a *double-edged sword*. It presents opportunities for scaling personalized, inclusive learning, but also raises profound questions about the role of the educator and the nature of learning itself. Faculty and institutions must navigate these changes thoughtfully. By centering pedagogy and ethics, and by preparing both teachers and students to engage critically with AI, higher education can leverage AI's strengths while mitigating its risks. Future developments should aim to blend human creativity and judgment with AI's power to analyze and adapt, creating a collaborative learning ecosystem. In doing so, AI can enrich higher education experiences for all stakeholders while safeguarding the core values of teaching and scholarship.

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(IJ-06) Personalized Recommendations In The Hospitality Industry
A Data Science Perspective

Shahinez Guetal

ABSTRACT

Since the year 2023 was assigned as the year of recovery for the global hospitality industry in the aftermath of the devastating COVID-19 pandemic crisis that plagued the world in 2019, there has been great anticipation and hopeful expectations for the industry to soar to unprecedented heights in the year 2024, as predicted by industry experts. The hotel market, which is an integral part of the travel and tourism industry, holds the distinction of being the largest market within this sector. Furthermore, it is important to note that these two markets, namely the hotel market and the travel and tourism market, are intricately connected and mutually dependent on each other. Within the hotel market, there exists a wide range of establishments that cater to the needs of customers seeking temporary lodging or sleeping accommodation, with a primary focus on providing comfort and ensuring safety and security. Additionally, the scope of the hotel market extends beyond mere accommodation, as it also encompasses a variety of services that are designed to meet the immediate needs of guests. These services may include the provision of meals, snacks, or beverages that can be consumed on the premises. Furthermore, after the outbreak of the COVID pandemic, the significance of delivering a personalized and individualized

experience to secure customer acquisition and retention has assumed a prominent and central position in this highly competitive business. As the landscape of customer technology continues to evolve, we are witnessing a notable transformation in marketing trends and expenditure. The realm of marketing technology itself is undergoing a rapid and accelerating evolution, playing a pivotal and indispensable role in enabling customers to successfully navigate through the ever-changing and dynamic technological advancements within the hospitality industry. So, it is obvious that the industry has endured nearly five turbulent years, including the Russia-Ukraine crisis. Now that the projections are favorable, in addition to eco-friendly travel, the global hospitality industry is poised to contribute significantly to the global GDP, with projections indicating that it will reach an all-time high of 17.24% in the year 2024, thereby surpassing its previous records. This upward trajectory in economic contribution is a testament to the resilience and adaptability of the industry as it rebounds from the challenges it faced in the wake of the pandemic and the Russia-Ukraine war. With these promising developments, it is evident that the global hospitality industry is on track to not only recover but thrive in the coming years, providing a much-needed boost to economies worldwide. Against this backdrop, this research paper provides a case study on Middle Eastern hotels that have achieved higher occupancy and RevPAR rates right after the COVID crisis eased. Therefore, the aim of this research paper is to present personalized recommendations derived from reliable data to forecast trends in the global hospitality industry. The paper provides recommendations on guest personalization and predicts trends that are poised to transform the industry, with a specific focus on Millennials and Generation Z. Through this research, conducted in the field of data science, not only can hotels benefit from the findings, but tour operators and industry experts can also utilize this valuable information to carefully plan and forecast their strategies from the year 2024 onwards. By examining these, stakeholders within the tourism sector can gain deeper insights into the best practices and strategies that have proven to be effective, thus enabling them to make informed decisions and stay ahead of the ever-evolving market trends. Moreover, it is undeniable that analyzing the behavior and mindset of travelers is of utmost importance for

hoteliers, as these tourists serve as the key agents of the industry. Therefore, this research paper has deemed it necessary to include an analysis of travelers' behavior along with growth areas within the hospitality industry. By understanding how travelers think and behave, valuable insights can be gained that will contribute to the development of successful strategies and initiatives.

RESEARCH METHODOLOGY

Primarily, this research paper is based on secondary research methods. The content this paper offers also has background of few referential readings. Links to those references are included in the last section of Future research. After compilation and careful evaluation of the data, attempt has been made to develop correlation among the statistics presented in the research paper sections. That evaluation is part of the Finding section. In this context, a logical argument arises regarding the authenticity of the data. Hence, data derived from reputable sources like United Nations Tourism, the World Economic Forum, Forbes.com, and booking.com has been duly considered. Lastly, this research delves into the major areas of growth in global tourism, based on statistical data.

INTRODUCTION

The recently published report on the global hospitality market in 2023 has provided valuable insights into the projected growth of this industry. According to the report, the global hospitality industry is set to witness a substantial increase in 2024 because it gained momentum from $4390.59 billion in 2022 to $4699.57 billion in 2023, showcasing a remarkable compound annual growth rate of 7.0%. This growth can be attributed to the stable economic progress produced by both developed and underdeveloped nations. **(Hospitality Global Market Report 2024)**. The United Nations Tourism website emphasizes the correlation between societal prosperity and the flourishing of the tourism sector, which parallels the growth observed in other economic sectors, including the hospitality sector. It means, the trickle-down effect of overall economic prosperity will ultimately have a positive influence on this industry. In fact, the UN Tourism Index, too,

forecasts a significant recovery in global tourism, attaining pre-pandemic levels by 2024, owing to the positive trajectory witnessed in 2023, where the industry achieved an impressive 88% recovery rate compared to pre-pandemic figures. **(UN Tourism 2024).** The analysis is being presented here as a case study to illustrate how, across the globe, the hotels in the Middle east region became the first beneficiaries of higher occupancy and RevPAR rates from societal and economic prosperity of the pre-pandemic level. Below are the graphical statistics taken from the UN Tourism website illustrating international tourist arrivals region wise.

**Figure 1**

International Tourist Arrivals, World and Regions
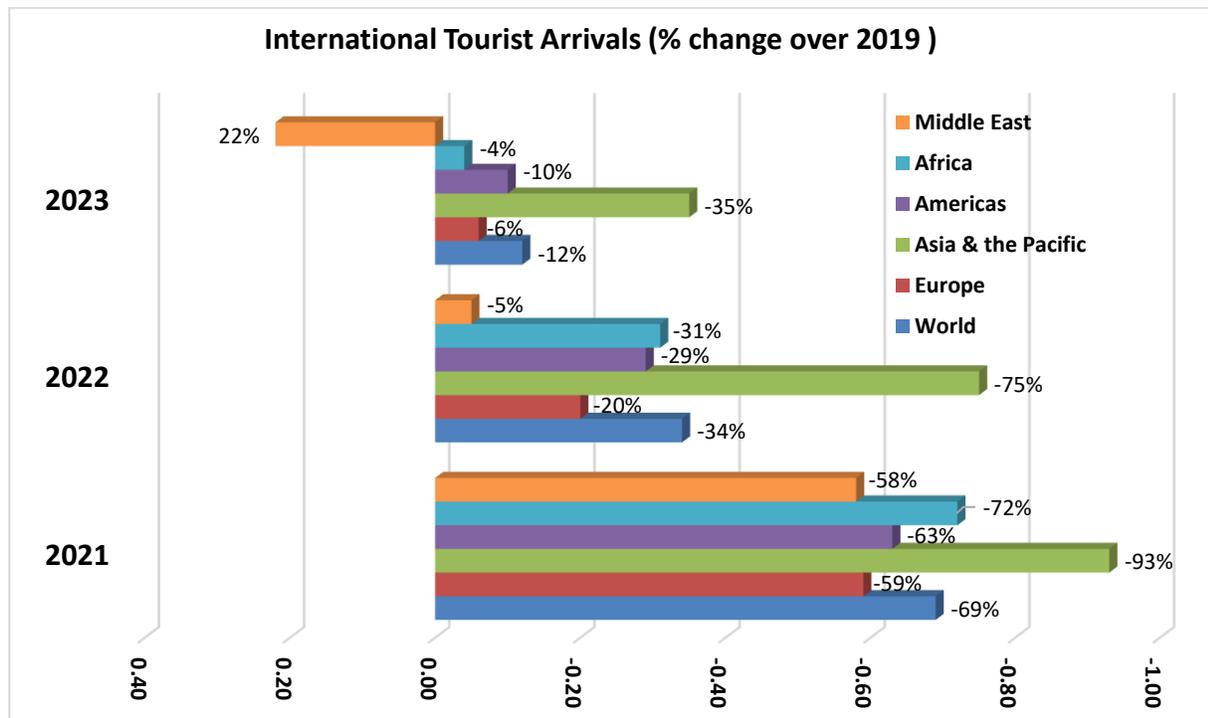
Note: **UN Tourism (International Tourist Arrivals, % Change over 2019)**

The representation of tourism data exemplifies a notable recovery trend in the Middle East, that has even surpassed its pre-pandemic levels of 2019 by 22%. On the other hand, Europe approached 94%, Africa 96%, and the Americas 90% of their pre-pandemic levels by the

end of 2023. The graphic illustration also shows that other regions have not achieved full recovery nor exceeded their pre-pandemic benchmarks. Since its' publication on the UN tourism website, the news of the Middle East being the winner to achieve and surpass the pre-pandemic level in tourism is considerably in the news across the web. The staggering growth in the Middle East's tourism sector, particularly evident in the aviation network, is instrumental in this recovery. For instance, Emirates Airlines, in collaboration with Philippine Airlines, has expanded its network, facilitating increased tourism. Consequently, there has been a concentrated effort by hoteliers and tour operators to promote the Middle East as a preferred destination for personalized and customized services for international travelers. The claim has strong backing as this strategic maneuvering has resulted in a notable increase in UAE hotel occupancy and RevPAR rates too, where occupancy rates surpassed pre-pandemic levels by 2.7% and reached up to 74.5% from January to July 2023. Whereas revenue per available room (Rav PAR) in the UAE, Saudi Arabia, and Egypt not only claimed back the strength of the pre-pandemic level, but also surpassed that level by 23% **(Alrashdi, 2023)**. Following is the statistical chart taken from the Emirates NBD website. Also, it is worthy to note that among the key metrics of the hospitality industry, occupancy rate and RevPAR are of great significance to evaluating performance.

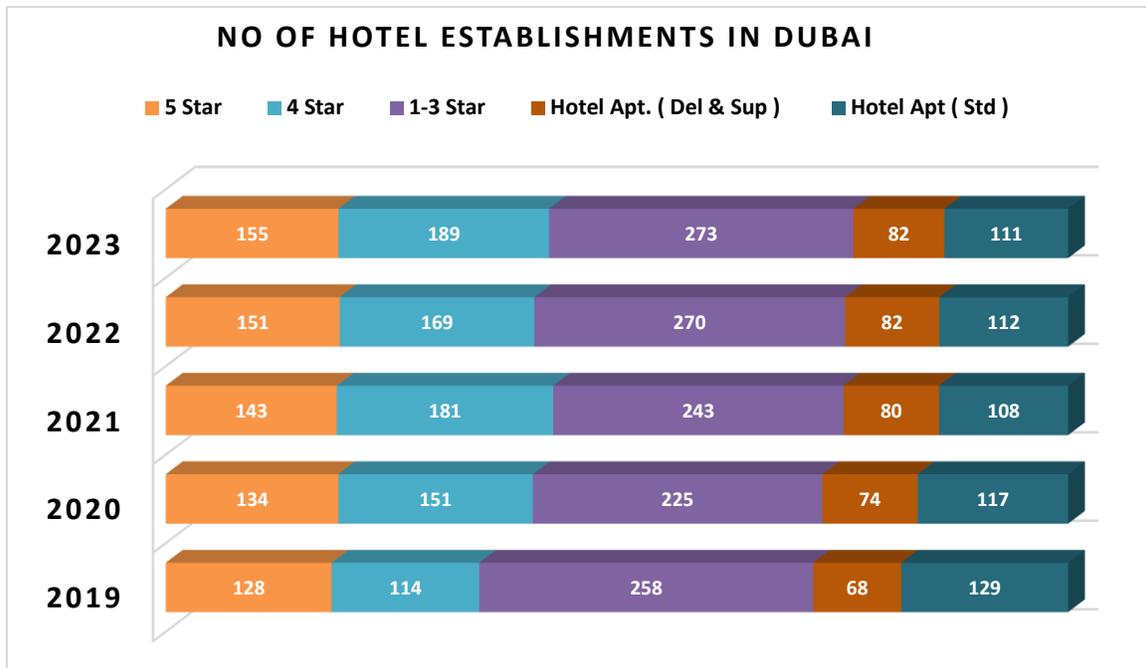**Figure 2**

Regional Tourism: Middle east leads the recovery.

Average RevPAR in the Mena Region
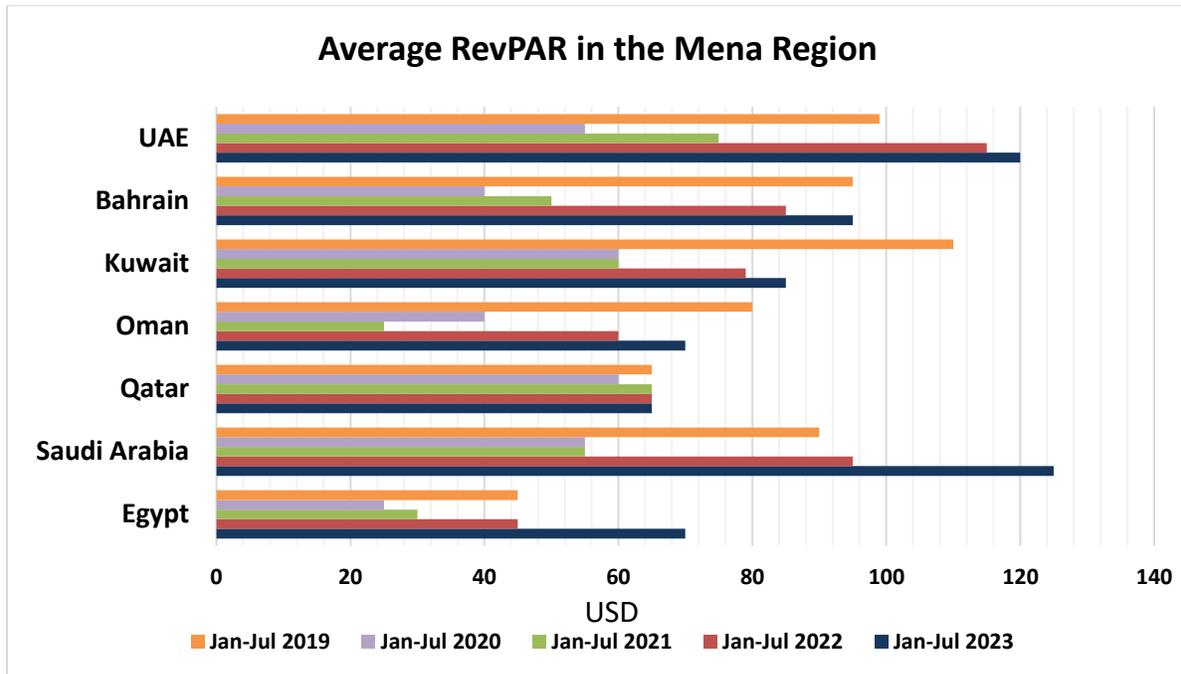
Note: **Source-STR, Emirates NBD Research**

Furthermore, in November 2023, the announcement of a unified visa, like the Schengen visa, by the Gulf Cooperation Council played a crucial role in the personalized and customized experience of international travelers visiting the region. This unified visa system aims to streamline the travel process for tourists visiting the Gulf countries, fostering a sense of ease and convenience. Moreover, the Gulf countries are actively working towards implementing visa and travel facilitation measures to enhance the overall travel experience in and around the Middle East, with a particular focus on stimulating tourism across the region **(UN Tourism 2024)**. By prioritizing the promotion of tourism, these countries are not only showcasing their rich heritage and diverse landscapes but also creating opportunities for economic growth and cultural exchange across major economic sectors, including the Middle Eastern hospitality industry. The state of Dubai is no exception to this approach and has produced encouraging numbers. Dubai's department of economy and tourism released data during the second half of the year 2023, showing Dubai being the

forerunner to becoming the most visited tourist place in the world. Dubai received 8.55 million visitors from January to June 2023, surpassing the 2019 pre-pandemic figure of 8.36 million visitors. This is the reason the state of Dubai had an additional 810 hotel establishments until June 2023, as compared to the figure of 773 hotels in June 2022 **(GCC-Hospitality Market Review 2023)**.

Figure 3

GCC-Hospitality Market Review

NO OF HOTEL ESTABLISHMENTS IN DUBAI

■ 5 Star   ■ 4 Star   ■ 1-3 Star   ■ Hotel Apt. (Del & Sup)   ■ Hotel Apt (Std)

| Year	5 Star	4 Star	1-3 Star	Hotel Apt. (Del & Sup)	Hotel Apt (Std)
2023	155	189	273	82	111
2022	151	169	270	82	112
2021	143	181	243	80	108
2020	134	151	225	74	117
2019	128	114	258	68	129

Note: **Source- The Government of Dubai Media Office, Department of Economy and Tourism, Government of Dubai**

OVERVIEW OF GUEST PERSONALIZATION IN THE GLOBAL HOSPITALTIY INDUSTRY

In the hospitality industry, personalization is the art of meticulously and intricately crafting

and shaping every aspect of the customer experience. The integration of digital technologies and the use of AI have given hoteliers a great opportunity to enhance the visitor experience and grow their businesses exponentially. It also helps them draft policies based on analytical data they acquire through technology. Personalization can further be explained through a process, and each phase of the process carries importance to achieving customer retention.

Figure 4
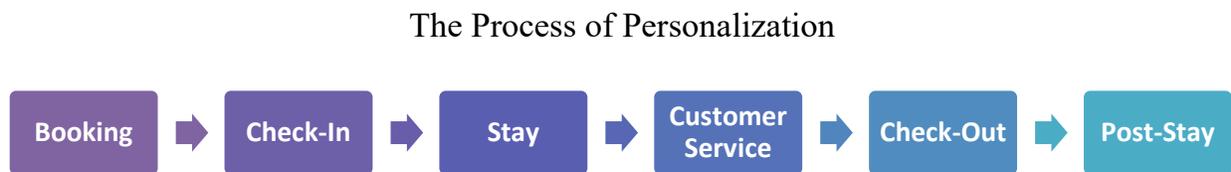
The Process of Personalization

Booking ➤ Check-In ➤ Stay ➤ Customer Service ➤ Check-Out ➤ Post-Stay

Note: **Source- From Medallia Market research 2023 Personalization Survey**

(n=1,749 hotel guests).

It is interesting to note that technology plays a pivotal role in each phase, and many hospitality outlets are making the most of the technology to boost their revenue throughout the process demonstrated above.

Figure 5

Top Hospitality technology trends.
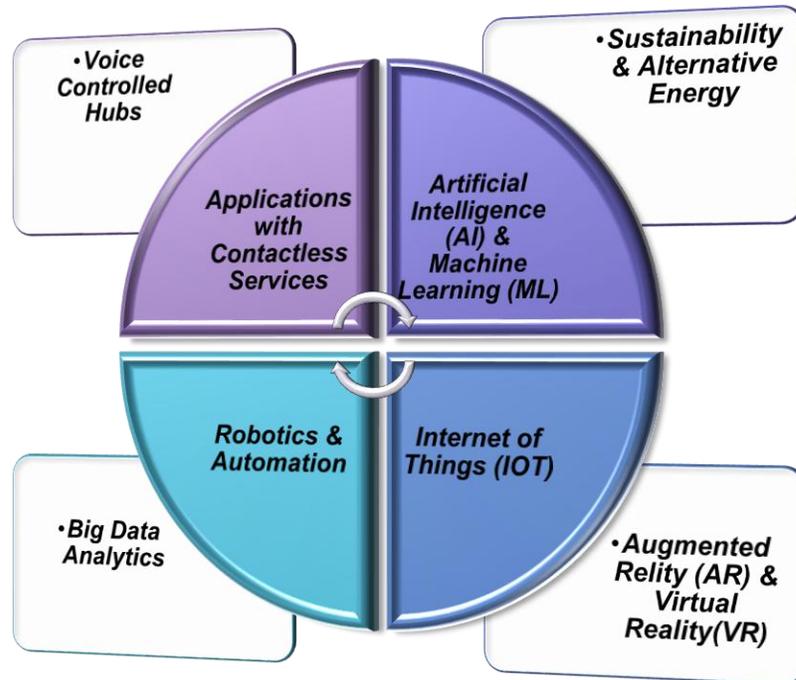
Note: **Source- Zheldak, P. (2024). Top Hospitality technology Trends in 2024**

According to the survey conducted by the University of Nevada-affiliated College of Hospitality, a significant percentage of respondents admitted allocating enough for the tech budget because technology has enhanced daily operations. Take the example of **contactless technology,** which has many useful purposes, including contactless check-in through apps. The survey also showed 70% of guests preferred hotels with advanced technological services, specifically the ones mentioned earlier, along with **voice-activated services** that enable them to control their room function to the extent of ordering room services and adjusting room lights. Also, the world is now benefiting from the advancements of artificial intelligence, which have brought about a revolution across the globe. It is undeniable that AI has also led to a revolution in personalized guest interaction, whereby hoteliers, using analytics, can now monitor guest data, be it behavioral or pertaining to social media and travel history. Seasonal fluctuation is undoubtedly evident in the hospitality sector. In this
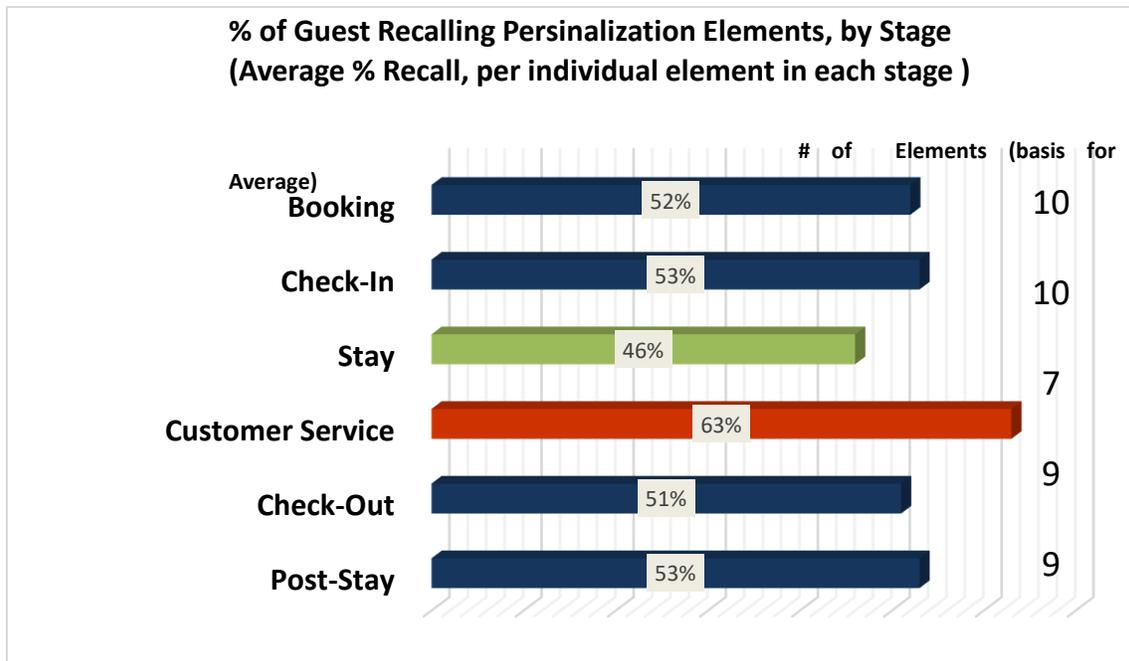
context, data analytics is available to rescue, as hoteliers can forecast demand through historical analysis and adjust their prices and resources based on predictive insight. Whereas AR and VR technologies have the power to present guests with a virtual tour of hotel destinations **(Zheldak, P. 2024)**. It implies that, to stay relevant in this competitive business, hoteliers must adapt to emerging trends. There are many examples of guest personalization experiences to observe. Marriott's tech-friendly Moxy Hotels promotes digital services for its guests, which include keyless entry and digital check-in and check-out, among many others. Another hospitality giant, Hayatt, offers a personalized application through which guests can customize their stay and preferences even before they arrive. Here, questions arise. Who are the recipients of these services? Historically, Millennials have been in the spotlight, but demographics have taken a new turn, and now Generation Z has stepped into the limelight. Ivana Johnston has written an article published on the Forbes website titled, **How Is Gen Z Reshaping Hospitality and Travel**? The article posted in November 2023 offers an extensive and comprehensive analysis of Gen Z, who possesses the ability to secure their position within the framework of the policies and strategies implemented by hotels and tour operators. Generation Z, characterized by individuals born between the mid-1990s and early 2010s, holds a considerable financial influence, estimated to be around a staggering $143 billion. This demographic constitutes a significant proportion, precisely 40%, of the overall consumer base within the hospitality industry. Moreover, as per **Euromonitor's voice of the consumer-travel survey**, it can be observed that there has been a transformation in the demographics of travelers. The current profile of travelers comprises young and empowered individuals who fall into various niche categories such as wellness worshipers, sports enthusiasts, and adventure seekers, among others. It is interesting to note that within these categories, the age group of Millennials, specifically those aged between 33 to 44, tends to assume a prominent role. This can be attributed to their inclination towards personalizing their travel experiences in accordance with their wellness and lifestyle preferences, thereby ensuring that their journeys resonate with them on a deeper level **(Bremner, C. 2023)**. Furthermore, the joint forces of both Generation Z

and Millennials are projected to amass a substantial market share of 45% of luxury products by the year 2025, thereby highlighting their growing influence and potential impact on the hospitality industry **(Johnston, I. 2023)**.

Also, a recently published special report, **Understanding Personalization Efforts in the Hospitality and Retail Industries** by US tech-research enterprise Medallia, delves even deeper into the intricate realm of the guest personalization experience, thereby emphasizing the importance of this aspect. The research conducted by the enterprise was based on the responses of 1,749 hotel guests about their recent visits or transactions in November 2023. The evaluation was rated on a scale from 0 to 10, with 10 indicating the best and 0 the worst guest personalization.

Figure 6

% of guest recalling Personalization elements

**% of Guest Recalling Persinalization Elements, by Stage
(Average % Recall, per individual element in each stage)**

Stage	# of Elements (basis for Average)
Booking — 52%	10
Check-In — 53%	10
Stay — 46%	7
Customer Service — 63%	9
Check-Out — 51%	9
Post-Stay — 53%	9

Note: **Source- From Medallia Market research 2023 Personalization Survey**

(n=1,749 hotel guests).

Figure 4 demonstrated the process of personalization, so, from Figure 6, we can now assess that the hotel's best chance to maximize guest personalization is during the guest stay, and it is obvious too because guests are in the stay phase and multiple factors are involved in terms of the customer services being provided by the hotel management. We can also call this phase the prime time of physical interaction between guests and hotel management. On the other hand, guests' expectations of a personalized experience are related to other key moments, specifically when they intend to book or even when they check in and out, leading up to the post-stay phase. Further, numbers from 0–6 represent low, 7-8 moderate, and 9–10 high guest personalization **(Medallia 2024)**.

This special report by Medallia Enterprise also provides a consumer personalization wish list for hotels. Here too, the report evaluates what guests expect to be rewarded based on their history. They also want customization that suits them best, based on their preferences. Overall, the special report signifies that the higher the guest personalization number, the greater the chances of fostering a profound emotional connection and forging an unbreakable bond of loyalty and devotion between the hoteliers and their guests, leading to a higher level of customer satisfaction. Once the hotel achieves these goals, it instills a deep sense of confidence and assurance in the hearts and minds of the guests, ensuring that they feel cherished, valued, and understood on a deeply personal level, prompting them to return time and time again, not as mere guests but as cherished members of an exclusive and privileged community. It's indeed a collaborative equation where hoteliers, too, can propel themselves to new heights of success through customer retention, which is indeed the prime objective of the hospitality industry. Lastly, it is of utmost importance for hoteliers to achieve a balance between guests' personalization and their privacy. It is highly likely that many would be reluctant to share personal details such as their contact number, residential address, and email address. In such a context, it would be advisable for hoteliers to limit the collection of sensitive information to a minimum, focusing primarily on gathering non-

sensitive data such as booking history and individual preferences.

MAJOR GROWTH AREA

The previous section of this research paper dealt with the matter of guest personalized recommendations at a micro level, delving into the intricacies and nuances. However, to broaden the scope and provide recommendations that encompass a wider scale, the focus of this section is set on offering recommendations at a macro level. By shifting the perspective from the individual to the collective, this section aims to provide insights and guidance that can be applied on a broader scale, taking into consideration the larger context and overarching objectives of hoteliers and tour operators.

SUSTAINABILITY ELEMENT IN TOURISM

Tourism watchdogs have rightly predicted that the sustainability element in tourism is destined to dominate the hospitality landscape from 2024 onwards. For consumers, it's a matter of seeking value for money; therefore, be it UN Tourism, Booking.com, or the World Economic Forum, all these reputable resources point to this fact, which will have far-reaching implications soon. Hotels' and tour operators' eco-awareness is a must now. According to the Booking.com Sustainable Travel Report 2023, 76% of the respondents expressed a desire to adopt sustainable travel in the coming years. Businesses with a high eco-awareness level have already started implementing eco-friendly strategies. Thus, Atlantis the Royal has started adopting Samsung LED signage to reduce their carbon footprints. This technology uses almost 50% to 70% less electricity than halogen. Additionally, Booking.com is also aiming to introduce the ethos of sustainable travel into mainstream operations, as stated by its CEO, Glenn Fogel. He also said that in 2022, Booking.com set out its ambition to be net-zero by 2040 as part of their climate action plan **(Booking.com 2023)**.

Figure 7

Fastest Growing Travel Categories in the World: Value 2023-2024

**Fastest Growing Travel Categories in the world Value
2023-2024**
(% Growth 2023-2024)
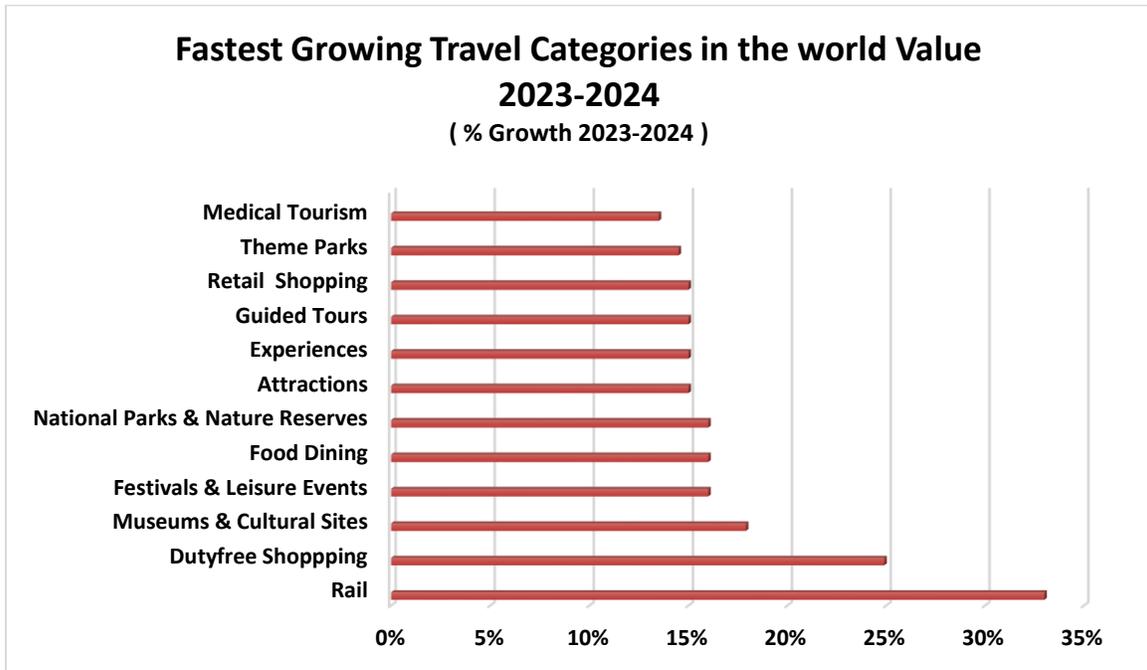
Note: **Source- Euromonitor International-passport Travel-Fixed 2023 exchange**

rate at constant prices

Before delving into the data presented in the Euromonitor survey regarding the fastest-growing travel categories, it is important to acknowledge that during the COVID pandemic, short-term rentals such as Airbnb experienced the highest growth rate. However, now it is the sustainable travel categories that are assuming the forefront position in terms of growth, with rail travel being the fastest-growing category, with 35.6% growth over 2023–2024. Since the carbon emissions produced by air travel are significantly greater than those generated by other modes of transportation, it has become increasingly common for eco-conscious travelers to opt for rail travel as a viable alternative means. The graph also gives an understanding of the conduct and attitude of the tourists. They are opting for destinations

that can additionally provide them with duty-free shopping. And particularly in Europe, museums and cultural sites throughout the region will prevail in the realm of hospitality **(Bremner, C. 2023)**.

Culinary tourism, too, is a prerequisite, as evident in the chart ranking. Travelers are eager to choose destinations that offer them the experience of local food and markets, making food a key driver in destination selection. Food also presents the opportunity to have cross-cultural experience and helps local businesses thrive as well. Also, the concept of sustainability encompasses many categories that demand careful evaluation by hospitality businesses. To determine the category to which they belong, hospitality businesses must engage in a thorough examination of their practices and policies. This assessment could involve scrutiny of various factors, including but not limited to reducing plastic waste, boosting the consumption of locally sourced food, implementing a robust recycling program, and adopting renewable energy sources as well as an efficient waste management system. Here, hoteliers and tour operators must remember the personalization process, and they can customize their services keeping in mind the findings of the survey.

FINDINGS

This research paper attempts to build a personalized recommendation opinion after careful evaluation of referential material. In fact, personalization in the hospitality business has a considerably broader scope that ranges from the micro to the macro level. Figure 1 of the introduction section showed the Middle East as the first region in the tourism world to reach and surpass the pre-pandemic level of 2019. It also demonstrated how a unified visa system in the Middle East streamlined the travel process for tourists visiting the Gulf countries, fostering a sense of ease and convenience to the extent that hotels achieved higher occupancy and RevPAR rates, as explained through figure 2. Dubai saw additional hotel establishments, as shown in figure 3 of the introduction section. It is indeed guest personalization on a macro level. And, if we place figures 1, 3 and 7 on the table; in a nutshell, we can develop a correlation.

Figure 7 displays the fastest-growing travel categories. The first, second, and third positions in this category were held by eco-friendly trains, duty-free shopping, and museums and cultural sites, respectively. Therefore, in the realm of appealing tourism experiences provided by the Middle East, an enticing package for global travelers consists of duty-free shopping at Dubai airport, environmentally friendly train connections between states, and an abundance of cultural sites- not to mention 4th ranked category of food dining, which also offers travelers cultural and local food experience.

On the other hand, examples of micro-level personalized experience of guests are, Marriott's Moxy Hotels tech-friendly ambiance and hospitality giant, Hayatt's personalized application through which guests can customize their stay and preferences even before they arrive.

CONCLUSION

There is an ample amount of material accessible across the internet related to the hospitality industry. Furthermore, there is no shortage of diversity in topics as well. The prosperity of global tourism will inevitably have a cascading effect on the hospitality industry, and the personalization of guests will also evolve in parallel with this process. This evolution does not cease here, as the behaviors of tourists are rapidly evolving too. Therefore, in this competitive business, it is imperative for hotels and industry experts to stay ahead in this race, as discussed in detail throughout the paper. The primary objective of this research paper was exactly this: to aid hospitality professionals in achieving this goal.

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(IJ-07) A Comprehensive Examination of Artificial Intelligence's Transformative Effects on Higher Education: A Case Study Analysis

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ABSTRACT

Artificial Intelligence (AI) has a remarkable impact on higher education through its transformative effects on personalized learning experiences as well as creative teaching and administrative processes.

This study explores the impact of AI in higher education through multiple case studies while examining both beneficial and detrimental aspects of technology integration. The research will tackle AI's ethical issues and offer guidance for its effective implementation at higher education institutions.

INTRODUCTION

Higher education institutions have implemented AI to create multiple learning opportunities and drive teaching and management innovations. Intelligent tutoring systems alongside language processors and learning machines have become widespread in education because AI introduction boosts learning results while increasing operational

efficiency, according to Luckin et al. (2016. The purpose of this study is to investigate how AI affects higher education and its transformational changes while evaluating its impact on students, educational staff, and administrators. A series of case studies enables the analysis of these aspects.

LITERATURE REVIEW

Background and Foundation Analysis

The beginnings of artificial intelligence trace back to the mid-20th century, based on Turing's 1950 research about machine intelligence that eventually led to the Turing Test. The official foundation of artificial intelligence as an academic discipline occurred during the Dartmouth conference in 1956, where McCasthy, Minsky, Rochester, and Shannon (2006) suggested the possibility of programming machines with intelligent behaviors. The 2021 research by Lytras et al. examines AI's transformative role in higher education institutions. According to Lytras et al. Through the use of AI technologies, academic institutions undergo transformation by adopting personalized learning models alongside automated content delivery systems and improved administrative procedures. Fundamental ethical obstacles such as data privacy and bias emerge from this research which demonstrates why strategic digital literacy integration is essential for responsible AI adoption in higher education. Correspondingly, Verma and Tomar (Eds.). The work of Verma and Tomar (Eds.) The study conducted by Verma and Tomar (2021) examines how the integration of AI into higher education modifies teaching strategies and impacts student learning experiences alongside academic research methodologies. Authors examine both the potential advantages of AI, including personalized learning and enhanced research methods, alongside major challenges related to ethics and faculty development requirements.

Furthermore, the investigation by Almaraz-Menéndez et al. The research by Almaraz-Menéndez et al. The 2022 study by Almaraz-Menéndez and his team explores strategic and governance aspects of implementing AI technologies in higher education. The study reveals

that ethical AI adoption requires academic institutions to create comprehensive policies and governance structures along with ethical guidelines. Researchers have produced key findings that demonstrate AI technologies stand to transform teaching approaches in higher education making it crucial for educators and researchers to utilize these technologies. The strategic analysis of policy and practice offers administrators and policymakers a framework to establish structures for responsible AI adoption.

Publications that examine both operational methods and strategic approaches help develop a full understanding of AI applications in academia.

PERSONALIZED LEARNING AND INTELLIGENT TUTORING SYSTEMS

AI-powered adaptive learning platforms deliver education that matches each student's requirements by presenting tailored content. Squirrel AI from China applies intelligent adaptive learning systems to detect knowledge gaps and create personalized learning pathways (Squirrel AI, 2024). The Korbit platform delivered substantial positive learning results to students through its customized and interactive learning approach (St-Hilaire et al., 2022).

AI IN COURSE CONTENT CREATION

Incorporating AI technologies into course development enhances the efficiency of creating educational materials. Research by Rouabhia in 2024 showed that ChatGPT can create a multimedia databases course that delivers original and high-quality educational content with efficiency. Educators now have access to powerful AI tools that enable them to create both broad and personalized educational resources.

ADMINISTRATIVE EFFICIENCY

Artificial intelligence drives significant changes in administrative operations at higher education institutions. Through AI deployment universities in Chongqing, China automate student enrollment and course registration processes to boost efficiency and reduce staff responsibilities (Zu, 2023). Skyline University College enhanced its administrative

operations with AI technology while solving technical issues and handling resistance to change (Skyline University College, 2023).

ETHICAL CONSIDERATIONS

Implementing AI solutions in academic environments generates ethical issues related to data privacy protection and algorithmic bias prevention, alongside the challenge of bridging the digital divide. O'Neil's 2016 study demonstrates that transparency and accountability in AI systems act as necessary measures to prevent discriminatory results. AI technology requires educational institutions to establish precise policies and guidelines to address ethical challenges while ensuring universal access.

METHODOLOGY

This study examines several AI implementations within the higher education environment through qualitative case study research methods. The research team collected information from academic journals, along with institutional reports, to develop a comprehensive understanding of AI's impact on these sectors.

CASE STUDIES

Case Study 1: Squirrel AI's Adaptive Learning in China

Squirrel AI developed the Intelligent Adaptive Learning System, which personalizes education by utilizing identified knowledge points to customize instruction to students' individual learning and needs. Squirrel AI's findings from 2024 showed that their method successfully enhanced student performance and engagement levels. (Wang et al 2023).

Case Study 2: ChatGPT in Course Development

The research by Rouabhia (2024) demonstrated how ChatGPT can create educational content by developing a multimedia database course. Research confirmed that AI technology could reduce the resources needed for course creation and cut down development time while maintaining high excellence standards.

Case Study 3: AI in University Administration in Chongqing, China

Zu's 2023 study examined how artificial intelligence impacted administrative functions at universities in Hechuan District, Chongqing, China. The implementation of AI systems led to improved management processes while enhancing student support and decision-making capabilities. The research identifies artificial intelligence as a transformative force for student experiences at higher education institutions through personalized learning and improved access to support services and information. Data-Driven Decision-Making and Improved Efficiency: According to the research findings, artificial intelligence systems enhance operational efficiency and cost savings and support data-driven decision-making processes at higher education institutions. Boddington's 2017 research validates this statement through its investigation of data privacy issues, along with security challenges and the need for transparent and accountable AI system integration.

The study also shows that artificial intelligence (AI) enhances educational results and develops research capacity in university settings, which aligns with Roll and Wylie's 2016 research, which indicates artificial intelligence can support personalized learning systems and adaptive educational materials as well as early intervention mechanisms. Technological advances have led to better learning outcomes and enhanced workforce proficiency.

Case Study 4: Skyline University College's AI Integration

Artificial intelligence applications at Skyline University College led to better educational customization alongside enhanced administrative performance. Despite facing technical challenges and resistance to change, Skyline University accomplished successful AI implementation outcomes and provided integration suggestions (Skyline University College, 2023).

DISCUSSION

The case studies show different ways artificial intelligence impacts higher education

institutions. AI systems enhance personalized education while reducing administrative tasks and refining course creation methods. The implementation of AI technology faces multiple challenges including ethical challenges and demands for adequate resources and training. Higher education institutions must establish strategic plans for AI deployment that mitigate risks and guarantee AI systems function to support human roles without replacing them.

CONCLUSION

Artificial Intelligence offers transformative potential for higher education by enhancing learning experiences and administrative processes, along with developing new teaching approaches. While AI integration presents substantial benefits, institutions must carefully manage the accompanying challenges. Educational institutions can leverage AI to its maximum potential for institutional growth by developing clear policies alongside investments in staff training and ethical considerations.

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(IJ-08) Advancements and Challenges in Software-Defined Networking

A Comprehensive Review of Solutions for Scalability, Security, and Resource Management in Wireless Sensor Networks

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ABSTRACT

Software-Defined Networking (SDN) is an innovative networking paradigm that decouples the control plane from the data plane, enabling centralized control and enhanced flexibility in network management. SDN's programmability allows for efficient resource allocation, dynamic configuration, and simplified network administration. This paper examines the key aspects of SDN, including its architecture, challenges in scalability, security risks, and performance optimization. SDN's integration with emerging technologies such as machine learning (ML), blockchain, and edge computing is also explored as a potential solution to its existing limitations. While SDN promises substantial improvements in network management, addressing scalability, security, and fault tolerance challenges remains crucial

to its widespread adoption.

Index Terms—Software-Defined Networking (SDN), Wireless Sensor Networks (WSN), Scalability, Security, Resource Management, IoT (Internet of Things), Edge Computing, Machine Learning (ML), Blockchain Integration, Fault Tolerance, Centralized Control, Flow Table Management, SDN-IoT Integration, Anomaly Detection, Multi-Controller Architecture, Network Slicing, Energy-Efficient Networking, Intrusion Detection Systems (IDS), Traffic Optimization, Adaptive Routing

INTRODUCTION

The increasing complexity of network infrastructures, driven by the growth of Internet of Things (IoT) devices, cloud computing, and data-driven applications, has outpaced the capabilities of traditional networking architectures. Conventional networks are heavily dependent on hardware and static con- figurations, which often lead to inefficiencies and performance bottlenecks. In contrast, Software-Defined Networking (SDN) offers a solution by separating the control plane (decision- making) from the data plane (packet forwarding). This decoupling allows for centralized management, making SDN highly programmable and adaptable to the changing needs of modern networks. SDN is thus viewed as a promising architecture for simplifying network configuration, automating network tasks, and improving resource management.

However, as SDN networks scale, several challenges arise, particularly in large, dynamic environments such as IoT and data centers. Key issues include the scalability of centralized controllers, the vulnerability to security threats due to the centralization of control, and the performance of SDN under heavy traffic loads. While SDN holds significant potential, solutions to address these challenges are still being developed and refined. This paper discusses the current state of SDN, its inherent challenges, and the innovative approaches that are being explored to overcome these barriers, with a particular focus on security, scalability, and performance optimization.

PROBLEM STATEMENT

SDN offers a promising alternative to traditional network architectures, but several issues must be addressed for it to be fully adopted in large-scale environments. The centralized nature of SDN introduces a single point of failure in the network, making it vulnerable to DDoS attacks, which could disrupt the entire network if the controller is compromised. Additionally, as the number of devices and flow rules in- creases, the performance of SDN networks may degrade due to bottlenecks in the centralized controller or issues with flow table management. Scalability remains a significant concern, particularly in ultra-dense environments like IoT networks, where managing massive volumes of data and traffic is challenging. Thus, this paper aims to investigate the scalability, security, and performance challenges of SDN and review the strategies being developed to address these problems.

LITERATURE REVIEW

1. SDN Architecture and Scalability Challenges

Software-Defined Networking (SDN) is an innovative network architecture that decouples the control plane from the data plane, enabling centralized control and enhancing the flexibility of network management. This architecture consists of three distinct planes: the application plane, the control plane, and the data plane, with the controller serving as the central decision-maker that directs the flow of data across the network. SDN's ability to provide dynamic and scalable network management has made it particularly suitable for complex environments such as data centers, Internet of Things (IoT) systems, and cloud platforms. Despite its advantages, SDN faces challenges, especially regarding scalability and security, particularly as the volume of data and network devices increases.

SDN's architecture is divided into three planes: the application plane, the control plane, and the data plane. The decoupling of the control plane from the data plane enables centralized decision-making, where the controller communicates with data plane devices (switches) to dictate the forwarding of packets. Nisar et al. reviews SDN, which separates the control

plane from the data plane, allowing for centralized control and greater flexibility in handling dynamic network demands, such as those in IoT and data centers. SDN's architecture consists of the application layer (for network apps), control layer (the network's "brain"), and data layer (network devices that forward packets). The OpenFlow protocol facilitates communication between the controller and devices, managing packet flows through flow tables and enabling simpler network configuration compared to traditional networks. SDN is used in various domains, including data centers, IoT, mobile networks, and cloud platforms, to optimize resource allocation, manage traffic, and enhance security. Despite its benefits, SDN faces security challenges in all layers, including DDoS attacks on the control layer and data breaches in the application and data layers, requiring further research to improve scalability, security, and integration with legacy systems [1]. In large networks, the central controller can become overwhelmed by the volume of data and requests it must handle, leading to performance bottlenecks.

Haji et al. compares SDN with traditional networking approaches, emphasizing that while SDN offers increased flexibility and easier network management, scalability is one of the biggest obstacles to large-scale deployment [2]. Yala et al. proposes a hierarchical, distributed SDN architecture enhanced with fog computing and AI-driven resource management to address scalability challenges in large-scale IoT environments. The architecture includes local controllers at the fog layer, regional controllers for coordination, and a global controller for network-wide policies, reducing latency and improving responsiveness by managing control decisions closer to IoT devices. Fog computing enhances efficiency by bringing computational resources closer to devices, enabling timely data processing and reducing transmission delays. AI techniques such as traffic prediction, dynamic flow management, and anomaly detection optimize network performance and ensure efficient resource utilization while enhancing security. The proposed approach offers practical solutions for scalability, latency reduction, optimized resource use, and improved security, making it highly relevant for large-scale IoT networks [3]. Similarly, Farooq et al. advocates for an adaptive multi-controller architecture for ultra-dense IoT environments,

where each local controller manages intra-zone traffic, and global controllers oversee inter-zone communication, ensuring scalability and efficient resource allocation [14].

While SDN offers significant benefits in terms of flexibility, ease of management, and centralized control, its scalability remains a critical challenge in large, dynamic networks. The hierarchical and distributed architectures proposed by researchers, such as those incorporating fog computing and AI-driven resource management, offer promising solutions to enhance scalability, reduce latency, and optimize resource allocation. By bringing decision-making closer to the devices and leveraging AI for proactive network management, these approaches improve network performance while maintaining security. However, ongoing research and development are needed to address the security vulnerabilities inherent in SDN, particularly in large-scale environments. As SDN continues to evolve, its integration with existing network systems and enhancement of its scalability will be crucial for its widespread adoption in future high-demand networks. [1]

2. Security Concerns in SDN

Software-Defined Networking (SDN) offers a centralized approach to network management, which enables dynamic, flexible control over network resources. However, this centralized nature also makes SDN networks particularly vulnerable to security threats, with the controller acting as a single point of failure. Research by Eliyan and Di Pietro highlights various security risks, including DDoS attacks and unauthorized access to flow rules, underscoring the need for robust security mechanisms in SDN environments. Several strategies, such as machine learning for anomaly detection, blockchain integration, and hybrid anomaly detection frameworks, have been proposed to mitigate these risks and enhance network resilience.

SDN's centralized nature makes it particularly vulnerable to security threats, as a compromised controller can bring down the entire network. Eliyan and Di Pietro identify several security risks in SDN, including DDoS attacks on the controller and unauthorized

access to flow rules [5]. They propose several strategies for mitigating these risks, such as efficient flow table management and the use of machine learning (ML) for anomaly detection in network traffic. Medhane et al. discusses the use of blockchain technology to enhance the security of SDN networks by providing a decentralized, tamper-resistant ledger for data transactions, which helps ensure the integrity of communication between IoT devices and the controller This presents a security framework for next-generation IoT environments, integrating blockchain, edge computing, and SDN to address growing challenges in data confidentiality, authentication, and resilience against attacks. It critiques centralized security approaches, which struggle with latency, computational load, and real-time adaptability, proposing instead a decentralized system using blockchain for secure, immutable transaction records that enhance data privacy. SDN is used for dynamic network management, isolating suspicious traffic and blocking attacks at the edge, while edge computing reduces latency by processing data closer to IoT devices. The framework includes a detailed algorithm for device registration and ongoing monitoring of device confidentiality, ensuring se- cure communication and quick threat response. Experimental results show the framework outperforms traditional systems in critical metrics like energy efficiency, packet delivery, and latency, demonstrating its potential for secure, scalable IoT applications [6].

Han et al. expands on this idea by integrating blockchain with reinforcement learning, enabling the network to dynamically adjust security policies in response to evolving threats, making SDN more resilient to attacks [7]. Additionally, Sahoo et al. utilizes machine learning to detect DDoS attacks by combining Support Vector Machine (SVM), Genetic Algorithms (GA), and Kernel Principal Component Analysis (KPCA) to identify malicious traffic patterns in real-time [8]. Tonkal et al. also employ feature selection techniques, such as Neighborhood Component Analysis (NCA), to improve the efficiency of machine learning based DDoS detection models [9]. Novaes et al. integrates Long Short-Term Memory (LSTM) networks with Fuzzy Logic to create an adaptive system that can dynamically identify and mitigate network anomalies, helping to prevent security breaches

[10].

Ahmed et al. presents a hybrid anomaly detection framework for Software-Defined Networking that combines statistical analysis and deep learning to enhance security against sophisticated threats like DDoS attacks. The two-stage framework uses statistical preprocessing to filter real-time traffic data for anomalies, reducing the computational load on the deep learning model, which employs a Convolutional Neural Net- work (CNN) for detailed classification. Testing in a large-scale SDN simulation demonstrated a detection accuracy of 98.7%, a reduced false positive rate of 2.3%, and a 40% reduction in computational load on the CNN, enabling near real-time detection. This approach effectively balances scalability and accuracy, adapting to evolving attack patterns in dynamic SDN environments. The framework highlights the potential of integrating statistical and AI methods to improve network resilience and security [25].

Patel et al. addresses insider threats in Software-Defined Network's by introducing a role-based access control (RBAC) framework tailored to manage roles and permissions. The framework defines hierarchical roles, such as network operator and security administrator, with specific permissions and dynamically enforces policies based on real-time context, such as network state or user behavior. An integrated monitoring mod- ule tracks actions against expected role behaviors, triggering alerts and access restrictions for anomalies. In simulations, the system blocked 95% of unauthorized actions while adding less than 5% overhead to network performance and enhancing ac- countability with detailed action logs. This approach provides a practical solution to securing SDN environments in critical sectors like finance and healthcare against insider risks [26]. While SDN provides significant advantages in network flexibility and management, its centralized architecture introduces substantial security risks that need to be addressed to ensure reliable and resilient network operations. Advances in ma- chine learning, blockchain technology, and hybrid anomaly detection frameworks show great promise in enhancing the security of SDN by enabling proactive defense mechanisms and adaptive security policies. Additionally, role-based

access control frameworks offer a practical solution for mitigating insider threats, further strengthening SDN's security posture. The integration of these technologies can significantly improve the robustness of SDN against evolving threats, making it a more secure and reliable solution for critical network infrastructures. However, ongoing research and the development of innovative security strategies remain essential to safeguarding SDN environments from increasingly sophisticated attacks.

3. Flow Management and Performance Optimization

Flow management is a pivotal challenge in Software- Defined Networking (SDN), particularly as networks expand and more devices are incorporated. A common issue in SDN is the limited capacity of flow tables in OpenFlow switches, which use Ternary Content Addressable Memory (TCAM) for storing flow entries. As network traffic grows, this limitation can lead to performance bottlenecks, including delays, packet drops, and overburdened controllers. Research by Isyaku et al. delves into these challenges, exploring flow table population strategies and security concerns such as denial-of-service attacks on the central controller. The section also highlights the potential of machine learning to improve flow management and security, while other studies by Alvizu et al. and Ahmed et al. discuss using machine learning and optimization approaches to address scalability and resource allocation issues in high-speed SDN environments.

Flow management is a critical issue in SDN, particularly as networks scale and more devices are added. OpenFlow switches, which are commonly used in SDN, have a limited amount of Ternary Content Addressable Memory (TCAM) space for storing flow entries, which can result in bottlenecks as the number of flow rules increases. Isyaku et al. examines the performance and security issues of flow table management in SDN, particularly with OpenFlow switches. A key challenge is the limited capacity of flow tables, which use expensive Ternary Content Addressable Memory (TCAM) and can lead to delays or packet drops when network traffic grows, compounded by the controller's processing load. The paper discusses two flow table population strategies: reactive (creating flow entries on-

demand, adding latency) and proactive (pre-populating flow tables, risking overflow). It also highlights the difficulties in updating flow rules dynamically, which can cause delays and impair network stability, and proposes solutions like FastRule and RuleTris for more efficient updates. Security concerns, such as denial- of-service attacks on the central controller, are addressed through techniques like FlowRanger and SDN-Guard, though they come with their own limitations, and the paper suggests using machine learning to improve flow management and security in future research [11].

Alvizu et al. explores how machine learning can improve scalability and resource optimization in high-speed mobile metro-core SDN networks. They propose using machine learning models like Support Vector Regression (SVR) and Artificial Neural Networks (ANN) to predict traffic patterns based on historical and real-time data, allowing for proactive resource allocation and congestion management. To complement these predictions, they introduce a matheuristic optimization approach that integrates mathematical programming with heuristic algorithms to optimize virtual network function (VNF) placement and data flow routing. This approach aims to improve network efficiency, reduce operational costs, and enhance scalability by dynamically adjusting to traffic demands. The strategies align with the project's goals of improving SDN scalability, performance, and energy efficiency, providing valuable insights for managing high-speed networks with fluctuating traffic [12]. Ahmed et al. also highlights the need for aggregated message processing to reduce the workload on SDN controllers, particularly in high-speed networks, where real-time decision-making is essential [16].

Managing flow tables in SDN is a critical challenge, especially as networks scale and traffic demands increase. Strategies such as proactive and reactive flow table population, along with innovative solutions like FastRule, RuleTris, and machine learning techniques, offer potential solutions to improve flow management, reduce latency, and enhance network security. The integration of machine learning models for traffic prediction and resource optimization, as proposed by Alvizu et al., further supports the goal of improving SDN

scalability and performance. Moreover, the use of aggregated message processing can alleviate controller workload in high-speed networks, ensuring real-time decision-making. Overall, these approaches provide valuable insights into addressing the performance and security bottlenecks of SDN, making it more efficient and resilient for large-scale deployments.

4. Integration with Edge Computing and IoT

The integration of Software-Defined Networking with edge computing has become crucial as the Internet of Things (IoT) continues to generate vast amounts of real- time data that demand swift processing. To address these challenges, researchers propose innovative architectures such as Software-Defined IoT (SDIoT) coupled with Edge Computing (SDIoT-Edge), which enables the processing of data closer to IoT devices, thereby reducing latency and enhancing resource efficiency. Several studies, including those by Rafique et al. and Farooq et al., explore how SDN can be combined with edge computing and multi-controller architectures to handle the dynamic, high-volume data flows characteristic of IoT networks. Security remains a major concern in IoT-SDN environments, with strategies ranging from lightweight security protocols to advanced anomaly detection techniques, as discussed by Iqbal and Zhang et al. Additionally, innovations such as network slicing and energy-efficient traffic engineering are explored to ensure reliable, sustainable, and scalable IoT deployments in smart cities and industrial environments.

The integration of SDN with edge computing has become increasingly important as Internet of Things (IoT) devices generate large amounts of real-time data that require quick processing. Rafique et al. propose Software-Defined IoT (SDIoT), coupled with Edge Computing (SDIoT-Edge), architecture that combines SDN with edge computing to reduce latency and improve resource efficiency by processing data closer to the devices [13]. This architecture is particularly useful for applications requiring real-time decision-making, such as autonomous vehicles or industrial automation, where delays in network communication could result in system failures. Farooq et al. discusses how multi-controller architectures

can be adapted for IoT networks, ensuring that local controllers can handle the large volumes of data generated by IoT devices without overloading the central controller [14].

Iqbal examines IoT security challenges and proposes Software-Defined Security (SDSec) integrated with Software- Defined Networking as a flexible and scalable solution. Highlighting IoT's vulnerabilities due to limited resources and diverse attack surfaces, the study explores centralized and decentralized SDN models, DoS/DDoS mitigation, data security, and anomaly detection frameworks like IoT SENTINEL. The paper discusses two primary SDN- IoT deployment models: centralized and decentralized architectures. In a centralized model, a single SDN controller manages the network, which simplifies control but can lead to a single point of failure. The decentralized model, however, distributes control across multiple controllers, improving resilience and scalability but complicating consistency across the network. The authors emphasize the need for standardized IoT security practices and advocate for lightweight, adaptive security protocols and collaborative efforts to enhance IoT resilience in a rapidly interconnected world [19].

Lui et la. explores the use of network slicing to enhance the integration of Software-Defined Networking and IoT systems in smart cities, addressing the challenges of diverse service requirements and quality of service (QoS) demands. The proposed framework divides the network into virtual slices dedicated to specific services, such as low-latency healthcare monitoring or energy-efficient grids, while maintaining isolation to prevent service interference. SDN controllers dynamically manage these slices, supported by machine learning algorithms that predict and optimize resource allocation based on real-time traffic patterns. Simulation results demonstrate significant benefits, including a 30% reduction in latency for critical applications, 25% improved energy utilization, and reliable service isolation. The study highlights the practicality of network slicing in managing complex smart city infrastructures, ensuring efficient and adaptable IoT deployments [22].

Zhao et al. proposes an energy-efficient traffic engineering framework for IoT networks managed by Software-Defined Networking to address rising energy demands from large-

scale IoT deployments. The framework dynamically adjusts network paths and switches underutilized devices into low- power modes using real-time traffic monitoring and predictive machine learning models. It balances traffic to minimize energy usage, proactively reactivates devices before traffic surges, and maintains performance with minimal latency increases. Testing demonstrated a 35% reduction in energy consumption, less than a 3% increase in latency, and over 90% accuracy in traffic predictions. This approach showcases the potential of SDN to create sustainable, energy-efficient IoT networks for applications like smart cities and industrial IoT [24].

Zhang et al. presents a cross-layer security framework to address the complex vulnerabilities in SDN's integrated with IoT networks. The framework employs layer-specific mechanisms, such as lightweight cryptographic protocols at the physical layer, traffic anomaly detection at the network layer, and policy-based access control at the application layer, to secure diverse IoT devices and systems. It integrates data across all layers to build a holistic threat model, enabling real-time responses like isolating compromised devices or rerouting traffic during attacks. Simulations showed a 97.4% detection rate for multi-layer attacks, an average mitigation time of 1.8 seconds, and minimal processing overhead of less than 5%. This approach is particularly relevant for securing complex environments like smart cities and industrial IoT, where device heterogeneity and cross-layer threats are significant concerns [28].

Lopez et al. introduces an SDN-based framework for IoT device identification and traffic profiling, aiming to improve security and resource allocation in IoT networks. The framework uses flow-level data to classify devices based on their unique traffic signatures, such as packet size distribution and communication patterns. It continuously profiles device traffic to detect anomalies like unusual data rates or unauthorized connections and applies dynamic traffic management policies based on device type. The system was tested on a network with 500 IoT devices, achieving 96% device identification accuracy, 94% anomaly detection, and an 18% reduction in congestion. This approach is particularly beneficial for

large-scale IoT environments, such as smart cities and industrial IoT, where device diversity and network complexity pose significant challenges [29].

Hassan et al. proposes a load-aware adaptive routing framework for IoT networks based on Software-Defined Networking to improve network efficiency in dynamic environments. The SDN controller continuously monitors network load, collecting data on link utilization and traffic volume to maintain a real-time view of the network. A custom routing algorithm dynamically adjusts paths, prioritizing underutilized links and considering factors like bandwidth, latency, and device priority. The framework also includes a machine learning component to predict traffic surges and proactively reconfigure paths, preventing congestion. Testing in an IoT testbed showed a 22% increase in throughput, a 15% reduction in latency, and a 35% improvement in link utilization balance, making it highly beneficial for smart cities, industrial automation, and healthcare applications [30]. The integration of SDN with edge computing and innovative frameworks like SDIoT-Edge presents a promising solution to the challenges posed by the growing demands of IoT networks. Research highlights various approaches to optimize network performance, including resource-efficient load balancing, energy-efficient traffic engineering, and enhanced security measures, all crucial for supporting large-scale IoT applications. Moreover, techniques such as machine learning, network slicing, and device profiling contribute to improving scalability, reducing latency, and increasing resilience in these dynamic environments. The potential benefits of these approaches are particularly evident in smart city infrastructure, industrial automation, and healthcare applications, where efficient, real-time network management is essential. As IoT networks continue to evolve, these advancements will play a key role in ensuring that SDN can effectively support their scalability, security, and performance needs.

5. Blockchain and Machine Learning Integration

The integration of blockchain and machine learning with Software-Defined Networking is emerging as a powerful strategy to enhance both security and performance in modern

network architectures. Researchers are exploring various methods to harness these technologies, with blockchain providing secure communication and data integrity, while machine learning offers adaptive and proactive security measures. Studies by Medhane et al., Han et al., and Assis et al. highlight the use of blockchain for secure device-controller communication and the role of machine learning in dynamically adjusting security and resource management strategies to respond to evolving network conditions. Furthermore, machine learning-driven solutions like intrusion detection systems and Quality of Service (QoS) optimization frameworks, as proposed by Alzahrani et al. and Kumar et al., showcase how these technologies can improve the resilience, reliability, and efficiency of SDN networks. Together, these advancements provide a robust foundation for ensuring the scalability, security, and performance required in next-generation IoT and real-time applications.

The integration of blockchain and machine learning with SDN is a promising approach to enhancing both security and performance. Medhane et al. explores how blockchain can be used to ensure secure communication between devices and the SDN controller, preventing unauthorized data access and ensuring data integrity in IoT networks [6]. Han et al. propose combining blockchain with reinforcement learning, enabling SDN to adapt its security and resource management strategies based on the current network state, improving both performance and security dynamically [7]. Assis et al. develops a deep learning-based approach using Gated Recurrent Unit (GRU) networks to detect and mitigate attacks, demonstrating the role of AI in improving SDN's resilience to evolving threats [18].

Alzahrani et al. explores enhancing SDN's security through a machine learning-based Network Intrusion Detection System (NIDS) utilizing algorithms like XGBoost, which achieved a high accuracy of 95.55%. Using the NSL-KDD dataset, the authors optimized the system by selecting key features and employing Min-Max normalization to improve detection efficiency and performance. The results underscore the effectiveness of machine learning in detecting diverse attack types and propose future advancements with neural

network architectures and broader dataset evaluations to develop robust, adaptive intrusion detection frameworks [17].

Kumar et al. introduces an AI-driven framework for optimizing Quality of Service (QoS) in Software-Defined Networking to support real-time applications like video conferencing and autonomous systems. The framework uses reinforcement learning (RL) to dynamically adjust routing paths, bandwidth allocation, and prioritization rules based on real-time traffic metrics such as latency and jitter. Testing on an SDN testbed showed a 28% reduction in latency, a 22% increase in throughput, and robust adaptability to fluctuating traffic loads through a self-learning feedback loop. This approach enhances the reliability and efficiency of networks handling critical real-time data. The framework offers significant potential for industries like telemedicine, live streaming, and autonomous systems that demand consistent high performance [27].

The combination of blockchain and machine learning with SDN holds significant promise for improving the security, adaptability, and performance of modern networks. By leveraging blockchain for secure communication and machine learning for real-time adaptive management, SDN can effectively address the challenges posed by increasingly complex and dynamic network environments. Research demonstrates how these technologies can optimize QoS, detect and mitigate attacks, and enhance overall network resilience. The promising results from various studies indicate that these approaches are key to supporting the high demands of IoT, real-time systems, and other critical applications. As these technologies continue to evolve, they will play a pivotal role in shaping the future of secure, efficient, and scalable SDN networks.

6. Fault Tolerance and Controller Management

Fault tolerance is a critical component for ensuring high availability and reliability in Software-Defined Networking, especially in large-scale deployments where network interruptions can significantly impact performance. Researchers have proposed several

strategies to enhance fault tolerance in SDN, focusing on distributed controller frameworks, redundant architectures, and robust security measures. Farooq et al. suggest a distributed controller framework with backup controllers that take over in case of failure, while Kreutz et al. emphasize the importance of standardization and interoperability to facilitate the implementation of fault-tolerant mechanisms, particularly in the context of 5G and cloud computing integration. Additionally, Aliyu et al. and Singh et al. propose trust management and redundant controller architectures to further secure and ensure network continuity, particularly in Industrial IoT environments. These efforts demonstrate the importance of designing SDN architectures that not only prioritize scalability and performance but also incorporate fault tolerance to maintain uninterrupted network services.

Ensuring fault tolerance in SDN is essential for maintaining high availability and reliability in large-scale networks. Farooq et al. propose a distributed controller framework that increases fault tolerance by providing backup controllers capable of taking over in case of a failure [14]. Kreutz et al. focuses on SDN's architecture and potential for large- scale, high-speed networks. The paper highlights network virtualization as a key enabler for SDN scalability, allowing multiple virtual networks to operate on shared physical infrastructure, enhancing resource utilization and flexibility. It also discusses the role of high-level programming languages and open interfaces, which simplify network management and allow for intuitive policy development in dynamic environments. SDN's separation of network services from hardware fosters innovation by enabling rapid testing and deployment of new solutions without hardware constraints. While acknowledging challenges in scalability and reliability, the paper emphasizes the importance of standardization, orchestration, and advanced control strategies for managing high-speed networks and proposes areas for future research, such as hierarchical control plane designs and enhanced security [15].

Aliyu et al. presents a trust management framework to enhance security in SDN's by addressing vulnerabilities from unregulated third-party network applications. The

framework incorporates three key components: Authentication, which uses token-based verification to restrict access; Authorization, which employs a Boolean Access Matrix to define precise application permissions; and Trust Evaluation, which calculates dynamic trust scores using Subjective Logic Reasoning (SLR) to monitor application behavior. These mechanisms collectively ensure that only authenticated and authorized applications with high trust scores can interact with the SDN controller, reducing risks of malicious activity. Experimental results validate the framework's ability to secure SDN environments, demonstrating its effectiveness in mitigating threats from third-party applications. Future work aims to enhance scalability, integrate machine learning for anomaly detection, and extend the framework to multi- controller SDN setups, advancing secure and resilient network infrastructures [21].

Singh et al. addresses the need for fault tolerance and reliability in SDN's for Industrial IoT (IIoT) by proposing a redundant controller architecture. The design uses multiple controllers in an active-standby configuration, with standby controllers continuously synchronizing with the active one to ensure seamless failover during failures. A lightweight synchronization protocol minimizes overhead by transmitting only incremental state updates, optimizing bandwidth and processing efficiency. Testing in an industrial testbed demonstrated an average switchover time of less than 1.5 seconds, no packet loss during transitions, and a 40% reduction in synchronization overhead compared to existing solutions. This architecture offers a practical, resilient solution for ensuring uninterrupted network operations in critical industrial environments [23].

Ensuring fault tolerance in SDN is fundamental to maintaining the reliability and availability of large-scale networks. The approaches presented by researchers such as distributed controllers, redundant architectures, and trust management frameworks offer practical solutions for enhancing SDN's resilience to failures. These mechanisms are particularly crucial as SDN becomes increasingly integrated with emerging technologies like 5G, IoT, and cloud computing, where the demand for seamless, high-performance

networks continues to grow. The advancements in fault-tolerant architectures and security frameworks, including those for industrial applications, underscore the necessity of building robust, scalable, and secure SDN infrastructures capable of withstanding potential failures. As SDN continues to evolve, these innovations will play a vital role in ensuring the stability and operational continuity of modern, mission-critical networks.

CONCLUSION

Software-Defined Networking offers many advantages, including programmability, flexibility, and simplified management. However, as this review shows, SDN's centralized architecture presents several challenges, particularly related to scalability, security, and performance. Solutions such as multi- controller architectures, blockchain integration, and machine learning have shown promise in addressing these challenges. Despite these advancements, more work is needed to optimize SDN's scalability and fault tolerance, particularly in the con- text of IoT and edge computing.

Future research should focus on developing more resilient and scalable SDN architectures, as well as further integrating SDN with emerging technologies like 5G and blockchain. These advancements will be crucial to meeting the demands of large-scale, high-performance, and highly secure networks. SDN will play an essential role in the future of networking, enabling more efficient, secure, and adaptive systems for a wide range of applications.

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