Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 06 June-2026, Page No.- 10542- 10548

DOI: 10.47191/etj/v11i06.30, I.F. – 8.595

Evaluating the Impact of Cloud-Based Media Transcoding on Performance, Reliability, And Scalability in Nepal

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ABSTRACT

Background: The rapid growth of digital broadcasting, IPTV services, and online streaming platforms in Nepal has significantly increased the demand for efficient and scalable media processing infrastructures. Many Nepali broadcasters continue to rely on traditional on-premises systems, including Integrated Receiver Decoders (IRDs), Moipro devices, and locally hosted servers, which frequently experience CPU/GPU overload, unstable satellite inputs, and audio-video synchronization issues.

Objective: This study investigates the technical, operational, financial, and infrastructural challenges faced by Nepali media houses in multi-channel transcoding and evaluates the feasibility of cloud-based and hybrid transcoding solutions within Nepal's unique infrastructure constraints.

Methods: A mixed-method research design was employed, combining structured surveys and semi-structured interviews with professionals from 11 media organizations in the Kathmandu Valley, representing 18.3% of approximately 60 registered media entities. Data were analyzed using descriptive statistics, proportion-based hypothesis testing (significance level: 0.05), and thematic coding. The Technology-Organization-Environment (TOE) framework and Diffusion of Innovation (DOI) theory provided the theoretical foundation.

Results: Survey findings revealed that 63.6% of surveyed organizations (7/11) experience frequent CPU/GPU overload, and 72.7% (8/11) face bandwidth bottlenecks. Downtime analysis showed that 54.5% experience monthly outages and 18.2% face weekly interruptions. Hypothesis testing confirmed that technical barriers (H1: Supported), organizational readiness (H3: Strongly Supported), and perceived benefits (H4: Supported) are the dominant factors influencing cloud adoption. Financial concerns (H2: Partially Supported) relate primarily to billing unpredictability rather than absolute cost.

Conclusion: Full cloud migration is currently impractical for Nepali media houses due to internet reliability and organizational constraints. A phased hybrid cloud architecture, maintaining on-premises IRDs and encoders while leveraging cloud services for backup, overflow management, and disaster recovery, represents the most viable and sustainable pathway. These findings provide empirical evidence and actionable recommendations for broadcasters, policymakers, and cloud service providers in developing country contexts.

KEYWORDS: Cloud Computing; Media Transcoding; Multi-Channel Broadcasting; Hybrid Architecture; Nepal; TOE Framework; Technology Adoption; IPTV; Digital Broadcasting

1. INTRODUCTION

The global media and broadcasting industry is undergoing a fundamental structural transformation driven by the proliferation of internet-connected devices, the widespread adoption of over-the-top (OTT) platforms, and exponential growth in online video consumption. By 2026, global video streaming traffic is projected to reach 4.5 zettabytes annually, compelling broadcasters to support simultaneous multi-platform content delivery across heterogeneous device ecosystems [1].

In Nepal, this digital shift is reflected in the rapid expansion of IPTV services, social media broadcasting, and online streaming platforms. The Kathmandu Valley, home to approximately 60 registered media organizations including television broadcasters, cable operators, and digital streaming providers, represents the most concentrated hub of broadcasting infrastructure in the country. However, a significant proportion of these organizations continue to operate legacy on-premises systems, including Integrated Receiver Decoders (IRDs), Moipro encoding devices, and locally hosted media servers, that were not designed for the scale or flexibility demanded by contemporary multi-channel, multi-platform broadcasting.

Multi-channel media transcoding, the process of converting live or recorded video streams into multiple formats, bitrates, and resolutions for simultaneous distribution across television, mobile, and web platforms, is central to modern broadcasting operations. Transcoding workloads are computationally intensive, requiring sustained high CPU/GPU utilization, and are highly sensitive to input signal stability, network bandwidth availability, and processing latency. Traditional on-premises systems,

constrained by fixed hardware capacity and manual operational workflows, are inherently ill-suited to the dynamic scaling demands of multi-channel environments, particularly during peak broadcasting hours.

Cloud computing platforms, such as Amazon Web Services (AWS) Media Live, AWS Media Connect, and Cloudflare Stream, offer compelling advantages through elastic resource allocation, distributed processing, and global Content Delivery Network (CDN) integration. However, the adoption of cloud-based transcoding in developing countries such as Nepal is impeded by a complex interplay of technical, financial, organizational, and environmental factors, including unreliable internet connectivity, foreign currency billing constraints, limited technical workforce capacity, and an evolving regulatory landscape shaped by the Government of Nepal's Data Center and Cloud Service (Operation and Management) Directive 2081 (2025).

Despite the global research interest in cloud media systems, empirical studies examining cloud transcoding adoption specifically within the context of Nepal's broadcasting infrastructure remain scarce. This study addresses that gap by conducting a systematic mixed-method investigation across 11 media organizations in the Kathmandu Valley, evaluating the current state of transcoding infrastructure, identifying adoption barriers, and proposing a practical hybrid cloud architecture tailored to Nepal's operational realities.

1.1 Research Questions

This study addresses the following primary research question:

- What are the major technical, operational, financial, and environmental challenges preventing Nepali media houses from adopting cloud-based multi-channel media transcoding systems?

Secondary research questions include:

- How do current on-premises transcoding systems impact performance, reliability, and scalability in Nepali media operations?
- What factors most significantly influence cloud adoption intention among Nepali broadcasters?
- What practical cloud or hybrid architecture can be recommended for Nepali media houses?

1.2 Hypotheses

Five hypotheses were formulated and tested:

- H1: Technical challenges (unreliable internet, bandwidth limitations, legacy system integration) significantly reduce cloud adoption intention.
- H2: Financial constraints (high costs, dollar-denominated payments, unpredictable billing) significantly reduce cloud adoption intention.
- H3: Organizational readiness (staff skills, training availability, management support) significantly increases cloud adoption intention.
- H4: Perceived benefits (scalability, reliability, cost savings, operational flexibility) significantly increase cloud adoption intention.
- H5: The 2025 Cloud/Data Center Directive significantly affects cloud adoption intention.
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2. BACKGROUND

2.1 Media Transcoding in Broadcasting

Media transcoding is the computational process of decoding a source video stream and re-encoding it into one or more output formats with different codecs, resolutions, bitrates, or container formats. In broadcasting environments, transcoding enables adaptive bitrate (ABR) streaming, which dynamically adjusts video quality based on real-time network conditions and client device capabilities. Modern transcoding pipelines support output profiles ranging from 4K Ultra HD (3840x2160, >15 Mbps) for smart televisions to low-bitrate mobile profiles (480p, 400-800 kbps) for cellular network delivery.

2.2 Multi-Channel Broadcasting Challenges

Multi-channel environments, where broadcasters must simultaneously transcode, package, and distribute 10 to over 100 independent video channels, present multiplicative computational demands. IPTV service providers in Nepal, for example, routinely manage channel portfolios exceeding 100 simultaneous streams, each requiring independent encoding, audio track management, and subtitle processing. The primary technical challenges in such environments include: (i) sustained CPU/GPU saturation during peak hours; (ii) audio-video synchronization degradation caused by Presentation ID (PID) changes in satellite IRD feeds; (iii) network bandwidth exhaustion affecting upstream contribution and downstream distribution; and (iv) the absence of automated monitoring and fault recovery systems.

2.3 Traditional vs. Cloud-Based Infrastructure

Traditional on-premises transcoding relies on dedicated hardware encoders, such as IRDs and digital video processing appliances, and locally hosted server farms. These systems offer high operational control and low network dependency but are

inherently inflexible, requiring capital-intensive hardware upgrades to accommodate workload growth. Cloud-based transcoding platforms address these limitations through elastic compute scaling, managed redundancy, and pay-per-use pricing, but introduce dependencies on high-bandwidth, low-latency internet connectivity that may not be reliably available in developing country contexts such as Nepal.

3. LITERATURE REVIEW

Huang et al. [2] proposed a hybrid cloud-edge framework for live video streaming, demonstrating that cloud-assisted transcoding improves scalability and system reliability while reducing end-to-end latency when combined with edge processing nodes. Their work established the foundational case for hybrid architectures as preferable to pure cloud deployments in latency-sensitive broadcasting scenarios.

Moina-Rivera and Garcia-Pineda [3] conducted a comprehensive review of cloud media video encoding, examining adaptive resource allocation techniques and dynamic workload scaling strategies. Their findings confirmed that software-based cloud transcoders significantly outperform traditional hardware encoders in handling fluctuating multi-channel workloads, though effective cost management during peak demand periods remains a critical implementation challenge.

The Broadcast Transformation Report (2024) [4], published by Haivision Systems, surveyed broadcasters across multiple regions and found that while cloud adoption for specific tasks such as live encoding and disaster recovery is increasing, full cloud-native broadcasting workflows remain the exception rather than the norm, with hybrid architectures dominating current industry practice.

Baral and Shakya [5] examined cloud adoption trends among organizations in Nepal and reported that hesitation to migrate critical workloads to cloud platforms is primarily driven by concerns about cost predictability, data sovereignty, and regulatory compliance rather than fundamental distrust of cloud technology. Their findings are directly relevant to the broadcasting sector's adoption dynamics identified in the present study.

A systematic literature review by ResearchGate (2024) [6] on cloud computing adoption in developing countries identified infrastructure instability, limited internet bandwidth, frequent power outages, and shortage of skilled technical personnel as the primary structural barriers to cloud migration, all of which manifest prominently in Nepal's media sector.

Collectively, these studies underscore a critical research gap: while global literature extensively addresses cloud transcoding architectures and adoption models in developed countries, empirical evidence examining these dynamics within developing country broadcasting contexts, particularly Nepal, remains sparse. The present study addresses this gap by providing primary survey and interview data from Nepali media organizations.

Table 1. Summary of Key Related Works

Author(s)		Year	Key Contribution	Limitation
Huang et al.		2022	Hybrid cloud-edge framework reduces latency for live streaming	Limited to low-latency scenarios; no multi-channel analysis
Moina-Rivera & Garcia-Pineda		2024	Dynamic cloud scaling outperforms hardware encoders in fluctuating workloads	Cost management during peak demand requires further investigation
Haivision (2024)		2024	Hybrid workflows dominate; full cloud-native broadcasting remains limited	Industry report; limited academic methodology
Baral & Shakya		2023	Nepal orgs hesitant due to cost predictability and regulatory concerns	Focused on general cloud adoption; not specific to media/broadcasting
ResearchGate SLR		2024	Infrastructure instability and skill gaps are primary barriers in developing nations	Broad scope; limited sector-specific analysis
Doyle et al.		2021	Scalable cloud video processing architectures for broadcast media	Developed country context; not applicable to resource-constrained environments

4. RESEARCH METHODOLOGY

4.1 Research Design

A mixed-method research design was employed, integrating quantitative survey data with qualitative interview findings to achieve methodological triangulation. This approach was selected to capture both the measurable, objective dimensions of transcoding infrastructure challenges (e.g., CPU utilization rates, downtime frequency, bandwidth availability) and the contextual, subjective dimensions of cloud adoption decision-making (e.g., managerial perceptions, organizational readiness, regulatory interpretation).

4.2 Theoretical Framework

The study is grounded in two complementary theoretical frameworks. The Technology-Organization-Environment (TOE) framework [7] explains technology adoption through three interrelated dimensions: the technological context (perceived benefits, compatibility, reliability), the organizational context (staff expertise, management support, financial capacity), and the environmental context (internet reliability, power stability, regulatory landscape). The Diffusion of Innovation (DOI) theory [8] provides complementary explanatory power by examining how attributes such as relative advantage, complexity, compatibility, trialability, and observability influence adoption timelines. The combination of these frameworks allows this study to examine both structural determinants and behavioral drivers of cloud adoption.

4.3 Sample and Data Collection

The broadcasting ecosystem of the Kathmandu Valley comprises approximately 60 registered media organizations, including television broadcasters, cable operators, digital streaming platforms, and hybrid media houses. A purposive sample of 11 organizations (18.3% of the population) was selected based on operational diversity, organizational size, and willingness to participate. The sample included 4 traditional television broadcasters (Nepal Television Corporation, Public Service Broadcasting NTV, Kantipur Television, Image Channel) and 6 IPTV/digital service providers (NITV Nepal Corporation, ClassicTech, Vianet Communication Ltd., DishHome Nepal, Subisu Net, WorldLink Communication Ltd.), providing representation across both organizational types.

Primary data were collected through a structured online questionnaire administered via Google Forms, covering: infrastructure capacity (CPU, GPU, storage), channel count, bandwidth availability, system downtime and failure rates, hardware maintenance costs, and cloud adoption awareness and readiness. Semi-structured interviews were conducted with technical managers and broadcast engineers to gather qualitative insights on workflow practices, staff competency, and organizational decision-making processes.

4.4 Data Analysis

Quantitative data were analyzed using descriptive statistics and proportion-based hypothesis testing. Response percentages were calculated as:

Percentage (%) = (Number of Responses / Total Respondents) × 100

Hypothesis testing was conducted at a significance level of $\alpha = 0.05$ using proportion-based statistical tests implemented in Jamovi. Qualitative interview data were analyzed through thematic coding using NVivo, with themes clustered around infrastructure, cost, training, and regulatory dimensions of cloud adoption.

5. RESULTS

5.1 Sample Profile

The sample comprised 11 media organizations representing 18.3% of the Kathmandu Valley's broadcasting ecosystem. Television broadcasters managed fewer than 10 channels each, while IPTV providers managed channel portfolios exceeding 100 simultaneous streams. This divergence in operational scale was found to be a significant predictor of infrastructure stress and cloud adoption openness.

5.2 Current Infrastructure — CPU/GPU Utilization

Of the 11 surveyed organizations, 7 (63.6%) reported frequent CPU/GPU overload during peak broadcasting hours, while 4 (36.4%) reported moderate resource strain. No organization reported consistent operation within optimal resource utilization ranges. These findings indicate widespread scalability limitations in existing on-premises transcoding infrastructure, consistent with the technical barriers described in H1.

Table 2. Survey Results: Infrastructure Performance Metrics (n = 11)

Infrastructure Metric	Count (n=11)	Percentage (%)	Interpretation
Frequent CPU/GPU Overload	7	**63.6%**	Critical scalability limitation
Moderate Resource Strain	4	36.4%	Operating near capacity limits

Insufficient Bandwidth	8	**72.7%**	Primary environmental constraint (TOE)
Manageable Bandwidth Levels	3	27.3%	Primarily larger IPTV providers
Monthly Downtime Episodes	6	**54.5%**	Persistent operational reliability concern
Weekly Interruptions	2	18.2%	Severe operational impact
Rare/Infrequent Outages	3	27.3%	Typically smaller broadcast organizations

5.3 Operational and Financial Findings

Annual hardware and maintenance costs ranged from NPR 200,000–1,000,000 (approximately USD 1,500–7,500) for traditional broadcasters to over NPR 1,000,000 (USD 7,500+) for IPTV providers. Despite this substantial expenditure, scalability remains fundamentally constrained by fixed hardware capacity. Internet bandwidth availability was dichotomous: broadcasters operated on connections below 100 Mbps while IPTV providers-maintained connections exceeding 100 Mbps. Internet instability was reported to affect transcoding operations with notable frequency by both organizational types.

Regarding monitoring practices, smaller broadcasters relied exclusively on manual monitoring with no automated fault detection tools, while IPTV providers and hybrid adopters employed combined manual and automated monitoring systems. Incident response times ranged from 1 minute to over 10 minutes for broadcasters and 5–10 minutes for IPTV providers, with hybrid cloud adopters demonstrating superior fault resolution speed attributed to cloud redundancy mechanisms.

5.4 Cloud Adoption Awareness and Concerns

All surveyed organizations demonstrated high awareness of cloud media platforms, specifically AWS Media Live, AWS Media Connect, and Cloudflare Stream. However, practical deployment was limited to trial usage or partial hybrid configurations in a minority of organizations. No surveyed organization had completed full cloud migration of primary transcoding workloads.

The four primary adoption concerns identified across organizations were: (i) data security and regulatory compliance; (ii) hardware dependency during the migration transition period; (iii) staff training deficits and limited cloud-skilled personnel; and (iv) internet reliability concerns. Regarding the 2025 Data Center Directive, responses reflected uncertainty rather than resistance, with organizations acknowledging increased regulatory clarity while expressing hesitation about implementation costs and procedures.

5.5 Hypothesis Testing

Table 3. Hypothesis Testing Summary ($\alpha = 0.05$)

Hyp.	Hypothesis Statement	Result	Support Level
H1	Technical challenges significantly reduce cloud adoption intention	Supported	Strong
H2	Financial constraints significantly reduce cloud adoption intention	Partially Supported	Moderate
H3	Organizational readiness significantly increases cloud adoption intention	Strongly Supported	Very Strong
H4	Perceived benefits significantly increase cloud adoption intention	Supported	Strong
H5	The 2025 Directive significantly affects cloud adoption intention	Moderately Supported	Moderate

H2 was only partially supported because the dominant financial concern was billing unpredictability and exposure to foreign currency exchange risk rather than the absolute magnitude of cloud service costs. H5 was moderately supported, with the 2025 Directive increasing institutional trust in cloud services while simultaneously introducing implementation complexity that delayed adoption decisions.

Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 06 June-2026, Page No.- 10542- 10548

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5.6 Comparative Architecture Evaluation

Table 4. Comparative Evaluation of Transcoding Architectures (Source: Primary Research, Chapter 4)

Evaluation Criteria	On-Premises	Hybrid-Based	Cloud-Based
Scalability	Low	High	High
Initial Cost	High	Medium	Low
Operational Control	High	High	Medium
Reliability	Medium (~92%)	Very High	High (>99%)
Internet Dependency	Low	Medium	High
Suitability for Nepal	Medium	**High ★ (Recommended)**	Low–Medium

6. DISCUSSION

6.1 Dominant Adoption Barriers

The study findings demonstrate that cloud adoption barriers in Nepal's broadcasting sector are multi-dimensional and cannot be reduced to purely technical or purely financial explanations. The strong support for H1 confirms that technical factors, particularly bandwidth limitations and legacy system integration complexity, are primary inhibitors. The very strong support for H3 reveals that organizational readiness, specifically the availability of cloud-competent technical staff, is the most significant positive predictor of adoption, consistent with DOI theory's emphasis on complexity as a determinant of adoption rate. The partial support for H2 adds nuance: broadcasters express concern not about cloud pricing per se, but about billing unpredictability and the exposure to USD-denominated costs in a NPR economy, a finding consistent with Baral and Shakya [5] and directly applicable to cloud service providers seeking to expand in the Nepali market.

6.2 Organizational Differences

A pronounced divergence was observed between traditional television broadcasters and IPTV service providers. Broadcasters managing fewer than 10 channels reported relatively stable operations but acknowledged significant limitations in scalability and automation. IPTV providers managing over 100 channels experienced substantially greater operational stress, with higher CPU/GPU utilization, more frequent channel interruptions, and greater reliance on combined automated and manual monitoring systems. This differential suggests that cloud adoption motivation and urgency are strongly correlated with channel volume, with IPTV providers representing the most immediate target demographic for hybrid cloud migration.

6.3 Implications of the 2025 Directive

The Government of Nepal's Data Center and Cloud Service Directive 2081 (2025) represents a significant policy development that is reshaping cloud adoption dynamics in the broadcasting sector. The moderate support for H5 reflects a dual effect: the Directive increases institutional confidence in cloud services by establishing a regulatory framework for data security and compliance, while simultaneously creating uncertainty regarding implementation requirements and cost implications. These findings suggest that additional clarificatory guidance and implementation support from the Ministry of Communication and Information Technology could materially accelerate cloud adoption.

6.4 Recommended Hybrid Architecture

Based on comparative architecture analysis and empirical findings, a phased hybrid cloud model is recommended as the most practical and contextually appropriate architecture for Nepali media houses. This model maintains on-premises IRDs and primary encoding hardware for core operations, while progressively integrating cloud services for secondary transcoding workloads, overflow management during peak hours, disaster recovery, and content distribution via CDN. This approach aligns with DOI

theory's concepts of trialability and observability, allowing organizations to build operational confidence and cloud competency incrementally before committing to large-scale migration.

7. CONCLUSION

This study provides the first systematic empirical investigation of cloud-based multi-channel media transcoding adoption in Nepal's broadcasting sector, drawing on mixed-method primary research from 11 Kathmandu Valley media organizations. The principal findings are:

- 63.6% of surveyed organizations experience frequent CPU/GPU overload and 72.7% face bandwidth bottlenecks, confirming the scalability crisis in current on-premises infrastructure.
- Technical barriers (H1) and organizational readiness (H3) are the strongest determinants of cloud adoption intention, with financial concerns (H2) relating primarily to billing predictability rather than absolute cost.
- Full cloud migration is currently impractical for Nepal's broadcasting sector due to internet reliability constraints and limited organizational cloud competency.
- A phased hybrid cloud architecture, integrating on-premises stability with cloud elasticity, represents the optimal transitional pathway for Nepali broadcasters.
- The 2025 Directive provides a positive regulatory foundation for cloud adoption but requires clearer implementation guidance to realize its full accelerating effect.

Future research should expand the geographic scope beyond the Kathmandu Valley, develop detailed cost-benefit analysis models for phased cloud migration in developing country broadcasting contexts, investigate cybersecurity challenges specific to cloud-based Nepali media workflows, and conduct longitudinal studies tracking adoption outcomes as internet infrastructure improves.

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