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# A Sociotechnical Perspective on Software-defined Networking Adoption in Large-Scale ISPs

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# A Sociotechnical Perspective on Software-defined Networking Adoption in Large-Scale ISPs

*Completed Research Paper*

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## Abstract

*This study investigates the sociotechnical factors shaping Software-Defined Networking (SDN) adoption within a major African Internet Service Provider (ISP). Employing a qualitative, single case-study, we conducted semi-structured interviews with network professionals across provisioning, support, automation, and core teams. Using a thematic analysis, we identified key technical challenges: vendor inconsistency, software maturity and reliability, lack of trust and stability, and cost-benefit consideration, while technical enablers include efficiency gained through automation, cost-benefit analysis and transformative potential. Social dimensions highlight knowledge gaps, skill erosion, developing a new way of thinking, resistance to change, and the need for a learning culture, while social enablers encompass factors such as perceived cost-effectiveness, strong vendor relationships, and evolving network professional roles. These findings are synthesized into a conceptual framework illustrating the dynamic interplay of technical and social dimensions. Grounded in the lived experiences of network professionals, this paper offers actionable insights for ISPs navigating SDN transitions.*

**Keywords:** Software-Defined Networking, Sociotechnical Systems, Internet Service Providers, Adoption, Africa

## Introduction

The rapid growth of the Internet, digitization, and the rise of technologies like the Internet of Things (IoT) have placed immense pressure on Internet Service Providers (ISPs) to maintain their network infrastructures with minimal downtime and high efficiency. As the demand for mobile and fixed broadband continues to surge, ISPs are increasingly challenged to adopt more scalable, agile, and cost-effective approaches to network management (International Telecommunication Union, 2023). In this context, Software-Defined Networking (SDN) has emerged as a transformative networking architecture, offering the potential to transform how networks are managed and operated. By separating the control plane from the data plane and centralizing network control, SDN promises greater flexibility, scalability, and efficiency, enabling ISPs to respond more effectively to the dynamic demands of modern digital ecosystems (Feamster et al., 2014; Narang, 2023). For example, traditional networks rely on a decentralized approach, where

individual devices (such as routers and switches) independently determine data flow, leading to inefficiencies in scalability and management. SDN addresses these limitations by decoupling the control plane (which makes routing decisions) from the data plane (which forwards data), centralizing network intelligence in an SDN controller (Hakiri et al., 2014). This architectural shift enhances flexibility, scalability, and operational efficiency, enabling ISPs to adapt more effectively to evolving network demands and optimize resource utilization.

However, despite its potential, the adoption of SDN is not without challenges. While SDN offers significant technical advantages, such as improved network programmability, automation, and centralized management, its successful implementation is influenced by a complex interplay of sociotechnical factors that are not yet fully understood (Chergarova, 2020; Hussain et al., 2022). Previous studies have identified several factors influencing the adoption of SDN, including technological maturity, standardization, legacy infrastructure integration, organizational readiness, the need for new skills, and shifts in organizational culture (Alhilal et al., 2018; López et al., 2022). Additionally, the human factor—encompassing network professionals' skills, attitudes, and resistance to change—has been recognized as a critical element shaping SDN adoption (Chergarova, 2020; Makhoere, 2021). However, despite these insights, there remains a gap in understanding how these factors interact in the specific context of ISPs, where unique operational and structural challenges may influence SDN implementation. To address this need, this study investigates the sociotechnical factors influencing the adoption of SDN within ISPs. Specifically, we answer the following research question:

*What social and technical factors influence SDN adoption within an ISP?*

By adopting a qualitative case study approach (Walsham, 1995; Klein & Myers, 1999), we explore the lived experiences of network professionals within one of Africa's top five ISPs, providing valuable insights into the sociotechnical complexities of SDN adoption. Our findings highlight the importance of a holistic approach that considers both technical viability and organizational readiness, emphasizing the need for effective change management, skill development, and clear communication of SDN's value proposition. Building on Sarker et al.'s (2019) argument that the sociotechnical perspective serves as an "axis of cohesion" in Information Systems (IS) research, we recognize that SDN adoption extends beyond technical feasibility to encompass broader social and organizational dimensions. Sarker et al. (2019) critique the tendency of IS research to either emphasize technical efficiency or focus solely on organizational processes, arguing that a balanced perspective is essential to understanding the mutual shaping of technology and social structures. In line with this view, our study examines SDN adoption not just as a technological innovation but as a process deeply embedded in existing sociotechnical systems within ISPs. By doing so, we contribute to a more holistic understanding of how technical capabilities and organizational dynamics interact to influence the success of SDN implementation.

This study contributes to the growing body of knowledge on SDN adoption in several ways. First, it provides a deeper understanding of the sociotechnical dynamics that shape the adoption process, addressing gaps in the existing literature on SDN implementation within ISPs (Chergarova, 2020; Hussain et al., 2022). Second, it offers practical insights for ISPs on navigating SDN adoption challenges, including training strategies, change management, and vendor collaboration. Finally, by focusing on the experiences of network professionals, this study sheds light on the evolving role of IT professionals in the era of SDN, highlighting the need for new skills and a shift in mindset from device-centric to systems-thinking approaches (Narang, 2023; Makhoere, 2021).

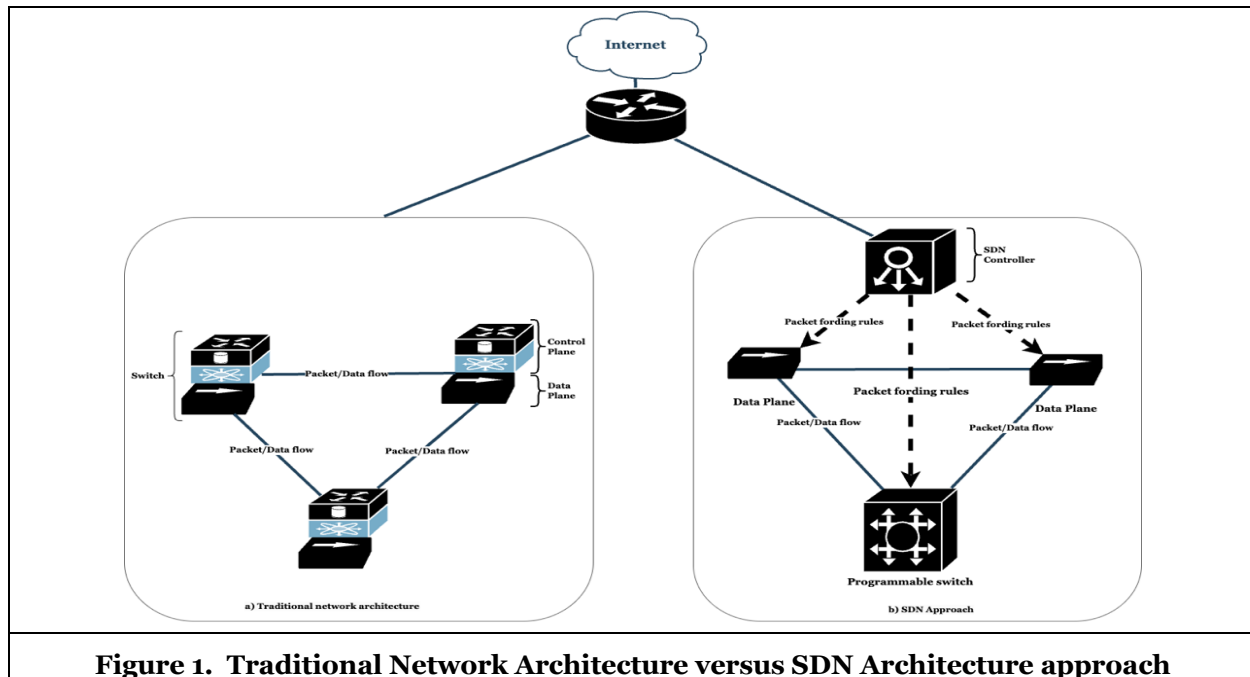
The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on SDN and IT adoption, establishing the theoretical background for the study. Section 3 outlines the research methodology, including data collection, and analysis. Section 4 presents the findings, focusing on the technical and social factors influencing SDN adoption. Section 5 discusses the implications of these findings for research and practice, concluding with limitations and avenues for future research.

## **Theoretical Background**

### ***Software-Defined Networking***

SDN, a transformative networking architecture characterized by the separation of the control plane from the data plane (Feamster et al., 2014), represents a paradigm shift in network architecture, fundamentally

redefining how networks are controlled and managed. Unlike traditional networking models, where control and forwarding functions are tightly coupled within individual devices, SDN decouples the control plane from the data plane, centralizing network intelligence in a software-based controller (McKeown, 2009) (See Figure 1 below). This separation enables enhanced network programmability, allowing administrators to dynamically configure, optimize, and adapt network behavior through software-defined policies rather than relying on proprietary, hardware-specific configurations. Beyond its technical capabilities, SDN also plays a transformative role in network management by enabling automation and reducing operational complexity. Traditional networks often require manual intervention for configuration changes and troubleshooting, leading to inefficiencies and increased administrative overhead. In contrast, SDN-driven automation allows for real-time traffic optimization, dynamic security enforcement, and improved fault tolerance, making networks more resilient and adaptive to emerging demands (Kim & Feamster, 2013). As SDN adoption continues to grow, its ability to enhance scalability, agility, and cost-efficiency positions it as a foundational technology for next-generation networking solutions.



**Figure 1. Traditional Network Architecture versus SDN Architecture approach**

While SDN offers unparalleled programmability, agility, and efficiency—making networks more responsive to modern digital demands (McKeown, 2009; Narang, 2023) and serving as a crucial asset for ISPs that provide the infrastructure for internet connectivity and services—it also raises concerns about the evolving role of network professionals and social processes. This motivates a sociotechnical perspective that integrates both technical and social factors.

To better understand the adoption and implications of SDN within the IS research, Authors 1 and 3 conducted a targeted search within AISEL for articles explicitly containing “software-defined networks,” “SDN,” or “software defined networking” in their titles. Because our intent was to identify studies with substantive focus on SDN, we deliberately used title keywords rather than searching full text; as a result, some IS journal articles that discuss SDN without including those exact terms in their titles do not appear in Table 1. This approach revealed that, while a notable contribution emerged from the Americas Conference on Information Systems (AMCIS) and Pacific-Asia Conference on Information Systems (PACIS), the majority of publications originated from the Hawaii International Conference on System Sciences (HICSS), reflecting that conference’s strong technical orientation. To mitigate potential bias, we also reviewed the reference lists of these proceedings papers and supplemented our table with relevant journal articles (e.g., *Sensors*, *Computer Networks*) that examine SDN adoption factors. Table 1 shows the selected papers chosen on the basis that they provide meaningful discussion and analysis of SDN concepts rather than merely mentioning the term. Although a few studies focus on SDN in broader contexts, such as cybersecurity, network performance, and emerging IoT/5G technologies, most remain at the proof-of-

concept or technical evaluation stage. This distribution underscores the need for further investigation of SDN's sociotechnical dimensions in IS settings.

<b>Table 1. Examples of Recent Studies on SDN</b>					
Authors	Year	Outlet	Methods	Key Findings	Recommendations
McAndrew et al. (2020)	2020	HICSS	Unsupervised Machine Learning (Functional PCA, K-means clustering)	Near real-time DDoS detection using unsupervised ML; detects attacks within two minutes.	Adopt adaptive unsupervised ML for DDoS mitigation.
Kundel et al. (2022)	2022	HICSS	Empirical study with real-world 5G standalone network deployment	Hardware acceleration significantly improves 5G user plane performance.	Leverage hardware acceleration for optimized 5G performance.
Liu et al. (2019)	2019	HICSS	Constraint Programming for Service Function Chaining Design	CP is effective for NFV/SDN network design; enhances flexibility and scalability.	Employ CP for scalable and flexible NFV/SDN deployments.
Shimanaka et al. (2019)	2019	HICSS	Software Defined Networking (SDN) based deception architecture	Deception networks can covertly study attackers by mimicking operational networks.	Utilize SDN-based deception networks for advanced cyber threat intelligence.
Byun et al. (2018)	2018	Pre-ICIS Workshop on Information Security and Privacy (WISP)	Review study on Source Address Validation (SAV) technologies	No single SAV method provides a complete solution; privacy remains a key challenge.	Combine multiple SAV approaches for comprehensive IP spoofing mitigation.
Whaiduzzaman et al. (2021)	2021	PACIS	Latency-aware framework for Internet of Vehicles using Fog Computing & SDN	Fog-based controllers reduce latency issues in IoV; enhances V2V communication reliability.	Integrate Fog Computing with SDN to enhance IoV performance.

Hsieh & Ku (2018)	2018	International Conference on Electronic Business (ICEB)	Machine Learning (KNN & Genetic Algorithm) for Gray Hole Attack Detection in SDN	Weighted KNN with GA effectively detects gray hole attacks in SDN with high accuracy.	Use ML-based techniques for robust anomaly detection in SDN security.
Hoang (2015)	2015	Journal of Telecommunications and the Digital Economy	Literature Review	Identifies enablers and barriers SDN.	Develop standardized northbound interfaces, adopt SDN incrementally over legacy infrastructure, and invest in hands-on training.

Most existing works on SDN in IS focus on technical proof-of-concepts or small-scale performance evaluations within controlled or simulated environments. For example, McAndrew et al. (2020) use unsupervised machine learning in an SDN testbed for DDoS detection, while Kundel et al. (2022) measure 5G user plane performance in a 5G-enabled SDN pilot. Constraint programming methods (Liu et al., 2019) are tested in network simulators, and deception-based security architectures (Shimanaka et al., 2019) are validated in lab contexts. Although Hoang (2015) offers a broad literature survey, none of these studies examine how SDN rollouts unfold within a large-scale ISP organization under real operational constraints. Consequently, there remains a gap in understanding SDN adoption from the ground up, how technical capabilities and social dynamics combine during an actual network transition. Our study responds directly to this gap by employing a sociotechnical, qualitative case study of network professionals inside a major African ISP.

### ***A Sociotechnical Perspective on SDN Adoption***

Organizations comprise not only software and hardware processes but also of people, physical objects, and geographical contexts (Bella et al., 2015; Sarker et al., 2019). Therefore, SDN adoption warrants an approach that considers both the technical and social dimensions within an integrated environmental framework (i.e., a sociotechnical system). The notion of “sociotechnical systems” highlights that the design and operation of any complex system can only be improved by integrating its social and technical dimensions within its environment (Sarker et al., 2019). In this framework, the technical dimension encompasses the tools and resources used to conduct day-to-day work activities in organizations. This includes technology (e.g., equipment, information, and techniques) and work activities (e.g., tasks and work organization). Meanwhile, the social dimension involves functions (e.g., organizational structure) that enable systems of authority, communication, and workflow by people who influence and/or perform work activities in organizations. This also includes organizational functions (e.g., skills, culture, and policy) and actors or human beings (e.g., human relations). Both the social and technical dimensions are embedded within the environmental dimension, which includes political, economic, and legal factors. This sociotechnical perspective broadens our understanding of SDN adoption in ISPs, offering a well-established framework for advancing our understanding of the social and technical dimensions while contextualizing their interactions in the studied environment.

Building on the sociotechnical perspective (Sarker et al., 2019) described above, existing literature reveals that both technological and social dynamics play critical roles in SDN adoption. On the technical side, SDN offers new solutions to conventional network problems but also introduces new challenges (Jefia et al., 2018). Key technological factors include SDN maturity and standardization, particularly OpenFlow (see, for example, <http://www.openflow.org>), which remains a concern due to the lack of robust and standardized protocols (Batool et al., 2019; Chergarova, 2020). Legacy infrastructure integration and compatibility present additional challenges, necessitating hybrid approaches for smooth transitions (López et al., 2022). Scalability and performance are crucial, with concerns about managing large SDN networks and ensuring reliable data transmission (Yu et al., 2018; Hussain et al., 2022).

On the social front, organizational dynamics, such as the skill gap and the need for training, as specialized skills in programming and networking are essential for operating SDN networks (Chergarova, 2020; Makhoere, 2021). Organizational culture and resistance to change also hinder adoption, highlighting the need for effective change management strategies (Alhilal et al., 2018). The literature emphasizes the importance of fostering a supportive organizational culture and adopting a systems-thinking approach to networking (Rebelo, Lourenço, & Dimas, 2019).

Moreover, several enablers and barriers influence SDN adoption. Enablers include cost reduction and efficiency, with SDN lowering both capital and operational expenditures (Alhilal et al., 2018; López et al., 2022). Enhanced network control and manageability, achieved through programmability and centralized control, are also significant drivers (Chergarova, 2020; Jefia et al., 2018). Additionally, SDN can enhance security through centralized policy enforcement and improved network visibility (Hussain et al., 2022). Barriers include legacy infrastructure and integration challenges, security concerns and lack of trust in SDN controllers, skill gaps, and the need for training, as well as the lack of standardization and interoperability between different SDN solutions (Batoool et al., 2019; Yu et al., 2018). Organizational culture and resistance to change remain persistent barriers, necessitating careful planning and effective change management (Alhilal et al., 2018). While much is known about SDN's technological development, research still lacks a full understanding of how sociotechnical factors interact with technical constraints to shape adoption and use in organizations. The literature acknowledges SDN's transformative potential, yet there is insufficient focus on how organizational culture, regulatory environments, and human expertise influence its successful implementation. This study seeks to bridge this gap by analyzing both technical and social enablers and barriers, providing a more holistic perspective on SDN's role in reshaping modern network infrastructures.

## Methodology

We employed a qualitative research design utilizing semi-structured interviews. This approach is informed by a sociotechnical perspective, which recognizes the interconnectedness of social and technical systems in shaping IT adoption (Sarker et al., 2019). Given the complexity of SDN adoption, a qualitative approach enables a rich, contextualized exploration of how individuals perceive, interpret, and experience this phenomenon within their organizational and social contexts. Our approach is consistent with seminal interpretive IS scholarship (Walsham, 1995; Klein & Myers, 1999) and is well suited to generating deep, nuanced insights into SDN adoption as an evolving sociotechnical process. By emphasizing subjective experiences, it allows us to uncover how organizational structures, cultural norms, and social interactions influence SDN implementation. Moreover, this perspective acknowledges that multiple realities exist and that IT adoption is not a linear process but one shaped by dynamic human-technology interactions within specific institutional and organizational settings.

### **Case Selection, Context and Data Collection**

Data for this study were collected through semi-structured interviews with network professionals at a leading South African ISP implementing SDN within its network. A single case study approach was employed, with purposive sampling (Patton, 2002) used to select an ISP that has strategically adopted SDN to enhance network agility, automation, and operational efficiency. The selected ISP is a subsidiary of one of Africa's largest telecommunications service providers and employs over 13,000 employees, making it a key player in the industry and an early adopter of SDN technologies in a highly dynamic and competitive environment (Walsham, 1995; Klein & Myers, 1999). While this study employs a single case, the selected ISP was chosen due to its operational scale and technological complexity, aligning with those of global Tier-1 service providers. Specifically, the organization's network reaches a population exceeding 500 million individuals across 47 African countries (for enterprise business-managed services) and serves more than 200 million customers (including its affiliate Safaricom).

Network professionals were selected from four distinct teams: *Provisioning*, *Support*, *Infrastructure/Core*, and *Automation* to ensure a diverse range of perspectives on SDN adoption. These teams were chosen based on their distinct roles, skillsets, and potential influence on SDN adoption. Their diverse perspectives, shaped by their different day-to-day tasks, provide insights into the social and technical factors influencing SDN adoption within the ISP, directly addressing the primary research question.

To capture a range of experience levels within each team, at least two network professionals were selected to represent junior, mid-level, and senior levels. This selection ensured diverse levels of experience and background, resulting in a sample size of ten network professionals. This diverse group provided insights into the multifaceted nature of SDN implementation and adoption within the ISP. The selection process was designed to ensure a heterogeneous sample reflecting the experiences and perspectives of the selected ISP, as recommended by Klein & Myers (1999). In total, ten participants were interviewed for this study (see Table 2). The interviews took place in autumn 2024, lasting between 36 and 58 minutes, with an average duration of 47 minutes. Each interview was transcribed word-for-word, and any identifying information was redacted to protect participant confidentiality. To ensure data security, all transcripts were encrypted and stored on password-protected servers, with access restricted to the research team. Interview materials are available online (<https://osf.io/h3awp>, Appendix 1). When referencing participant statements, the following format was used: “Participant X(Y, Z)” The letter ‘X’ indicates the participant’s unique number, Y is the team they are in, and Z is their level ranging from 1 – 3 in their respective teams.

Participant (*alias)	Team	Support Level	Years of Experience	Interview time (min)
P1/*Participant 1 (A, L2)	Automation	2	18	54
P2	Automation	1	2	36
P3/ *Participant 3 (P, L3)	Provisioning	3	9	43
P4	Automation	3	10	44
P5/ *Participant 5 (S, L1)	Support	1	12	46
P6	Provisioning	2	14	40
P7/ *Participant 7 (C, L3)	Core Network	3	24	58
P8	Support	1	16	50
P9	Core Network	3	15	49
P10	Core Network	3	16	50

## Data analysis

We adopted Braun and Clarke’s (2006) thematic analysis approach to systematically analyze our qualitative data, enabling us to identify, interpret, and analyze patterns while ensuring that findings remained grounded in participants’ experiences. Our analysis was primarily inductive, allowing themes to emerge organically from the data rather than being predetermined by a theoretical framework. However, as our understanding deepened, we engaged iteratively with existing literature to contextualize and refine our emerging insights. The analysis began with immersion in the data, where interviews were transcribed verbatim and read multiple times by authors 1 and 2 to develop a comprehensive understanding. Reflexive notes were taken throughout this process to document initial impressions and potential patterns. Using NVivo software, we conducted open coding, systematically identifying recurring words, phrases, and concepts within the transcripts. This data-driven coding process ensured that the participants’ narratives shaped the coding structure, rather than fitting the data into pre-existing categories.

Once initial codes were established, all the authors examined patterns across the data and began grouping related codes into broader themes. At this stage, recurring concepts such as technology maturity, standardization challenges, training and skills, and organizational culture became apparent. To assess data saturation, author 1 and 3 monitored whether additional interviews yielded new codes or themes; by the eighth interview, no novel themes had emerged, and the final two interviews served only to confirm existing patterns. This systematic check for saturation assures that our sample of ten network professionals captured the key sociotechnical factors. These themes were then iteratively reviewed and refined to ensure coherence and consistency, with peer debriefings within the research team helping to scrutinize coding decisions and validate emerging insights.

As the themes developed, we articulated their defining characteristics and explored their interconnections within the broader sociotechnical landscape of SDN adoption. Engaging with existing theoretical perspectives (Klein & Myers, 1999; Sarker et al., 2019) at this stage allowed us to situate our findings within established research on IT adoption, organizational culture, and technological transitions.

Finally, our findings were presented narratively, integrating direct participant quotations to illustrate key insights and provide contextualized explanations of the factors influencing SDN adoption. This iterative and reflexive approach ensured that our analysis remained deeply embedded in participants' lived experiences, while also contributing to broader theoretical understandings of sociotechnical dynamics in IT adoption.

## Findings

The findings section presents a detailed exploration of the factors influencing SDN adoption in ISPs, organized around two main dimensions: technical and social. First, we present the technical challenges and enablers, followed by an analysis of the social challenges and enablers. The section concludes by synthesizing these insights into a conceptual framework (Figure 2), which integrates both dimensions to illustrate the dynamic interplay of sociotechnical factors shaping SDN adoption.

### Technical Challenges Influencing SDN Adoption

#### *Vendor Inconsistency*

SDN solutions often require network re-architecture or have limitations that impact which architectures are feasible. Participants 3(P, L3) explained: *“Some vendors **require more planning** than the others. Some vendors actually require you to have more foresight in terms of planning. And if you miss out on something, you could miss out something potentially big, and you could obviously stall how we implement this SDN rollouts to the clients.”*

Similarly, Participant 6(P, L2) noted: *“In a initial stage there's a whole lot that you have to cover and you have to make sure that you don't miss so that you know you it's an easy or **a smooth integration** and you know. The customer can function proper with the with the integration with minimal issues.”*

Beyond planning requirements, vendor origins differ, with **diverse backgrounds**. Participant 9(C, L2) observed: *“Some of these vendors actually started out to do SD-WAN and other vendors needed to jump on the bandwagon, right? So, I mean, they had a different product where maybe they were doing firewalling, or they were doing cloud optimization, and then they jumped on the SD-WAN bandwagon, you know? So first things first, they did, their function first and then SD-WAN on top of it. So yes, they do operate quite differently.”*

Table 3. Code-to-Theme Mapping (Example: “Vendor Inconsistency”)		
Quotation:	Code	Theme:
<i>“some vendors require more planning than the others. Some vendors actually require you to have more foresight in terms of planning”</i>	Requires more planning	<b>Vendor Inconsistency</b>
<i>“you have to make sure that you don't miss so that you know you it's an easy or a smooth integration and you know”</i>	Needs smooth integration	
<i>“so, I mean, they had a different product where maybe they were doing firewalling, or they were doing cloud optimization”</i>	Diverse background	

Table 3 shows how we moved from code to themes (three key codes: “requires more planning,” “needs smooth integration,” and “diverse backgrounds”). We applied this same coding-and-grouping process to each of the other themes named below.

### **Software Maturity and Reliability**

One problem that stems from the feature limitations is that vendors are constantly trying to catch up, which sometimes introduces new issues and bugs into the network. Participant 9(C, L2) elaborated:

*“The issue I have seen with SD-WAN is that all these vendors are trying to compete with one another right, and they really **trying to push out new features** and trying to get ahead of one another. And in doing that, they're trying to do this too fast, and they opening up a lot of a lot of bugs, so at no matter what point we are in. Every time you know there's a new upgrade fix in one thing, there seems to be a bug affecting something else and. This is across all the SD Wan vendors.”*

While SDN takes care of many traditional complexities, it introduces new ones, particularly in the form of software bugs. Participant 10(C, L2) highlighted: *“in a traditional legacy network, you, you're changing a lot of sort of network configuration errors, or software bugs. I found that almost proportionally has shifted into, I mean, the amount of times I've seen a **forwarding bug** be as detrimental as you know, someone doing switchport trunk allowed VLAN [This command, if executed on an existing trunk, would wipe all other Virtual Local Area Networks (VLANs), potentially causing a significant outage.]”*

### **Lack of Trust and Stability**

SDN still lacks the proven track record of stability that some traditional networking technologies have established. Participant 10(C, L2) expressed: *“We saw a switch that was up, that was running “Vendor B” OS 12 for 18 and a half years. That switch is old enough to start drinking, if you know what I'm saying. You we need to get SDN to that point and regardless of the vendor, if you if you can give a **very stable product**, you can get that in the top of everyone's minds.”*

### **Cost-Benefit Considerations**

The high upfront costs of SDN can be a significant constraint. Participant 7(C, L3), who is manages vendor onboarding, emphasized: *“**the cost of SDN is a little bit prohibiting** for operators to invest”* and further explained **how perceived costs hinder adoption**, urging operators and vendors to revisit pricing: *“The **operators need to come to the party if they want an adoption of SDN**. They need to come to the party in terms of coming with the **right pricing models**, as well as how they can come to the party on the price itself.”*

### **Communicating and Demonstrating Value**

Due to SDN's high initial costs, ISPs must clearly articulate its business value to justify investment. Participant 7 (C, L3) observed: *“**Operators not having the appetite**, you know they're failing to see how do we **productize**”* and further explained that *“we need to do a lot of work in terms of selling, taking the, what are the products. So besides operational efficiency saving on the cost. You know, efficiencies in the business, most of those are more cost saving, cost reduction type of exercise, but we're not doing enough in terms of what new products can we launch on SDN, you know, on-demand type of services, you know?”*

It was further emphasized that ISPs must demonstrate the added value: *“There's a lot of work being done around by the OEM's [Original Equipment Manufacturer] building SDN, but until we can roll it out and **have real use cases**, you know, and by roll out, I mean like massive roll out, you know the technologies like segment routing. You know, rolling out controllers. SDN controller, domain controllers and the hierarchal controllers...and being able to demonstrate to customers you know the value of SDN, not just being a marketing shmele, you know. So we can demonstrate customers, OK, here is an on-demand services...and that we can make a case for SDN, and I think there there's still a room there to craft products that are specific to SDN.”*

## Technical Enablers Influencing SDN Adoption

### *Efficiency Gained and Automation*

SDN brings significant efficiency and automation. For instance, Participant 10 (C, L2) emphasized the **intuitive nature** of many SDN controllers: *“Generally, I mean if somebody can use Facebook, they can, they can drive something like this [referring to SDN controller], right? They just need to understand basic networking concepts, and you know, the infrastructure, the software-defined component, handles all of the heavy lifting.”*

Furthermore, service orchestration and provisioning are enabled by SDNs orchestration layer. Participant 7(C, L3) explained: *“I mean, we talk about SDN, you know, generally we just talk about. Not just the SDN at the network layer also the orchestration layer that comes with it. You know the **ability to automate, you know service provisioning, service chaining and all of that**”.*

Building on that Participant 10(C, L2) noted: *“We sat down and predefined what all of these services are and anything that comes in is just another one of these services, right? Just with a different name and a different IP.”*

Finally, one of the end goals for ISPs is to offer Network as a Service (NaaS), as envisioned by Participant 7 (C, L3): *“With that will come an integration of these various SD-WAN for, you know for these SDN on the transport SD-WAN [Software-defined-Wide Area Network], SDN for the Data Centre. All of this needs to **be stitched together somehow via some form of a high-level orchestration** in SDN layer. So I think it's unavoidable if you want to be able to offer, you know, Network as a service”*

### *Cost-Benefit Analysis*

Some SDN solutions demonstrate clear cost benefits. Participant 9 (C, L2) explained how SD-WAN, a sub-domain of SDN, reduces expenses and increases flexibility: *“There's so much adoption of the SD-WAN, is because in the past you **needed MPLS to connect those branches, which was quite expensive**” and further described the flexibility offered by SD-WAN: *“with SD-WAN, I mean you can use any underlay medium, and you have a lot more **control over that traffic** what gets sent where.”**

### *Transformative Potential*

SDN can potentially transform the networking landscape by enabling cross-domain service orchestration. Participant 7(C, L3) articulated this vision: *“With that will come an integration of these various SD-WAN for, you know for these **SDN on the transport SD-WAN, SDN for the Data Centre**. All of this needs to be stitched together somehow via some form of a high-level orchestration in SDN layer. So, I think it's unavoidable if you want to be able to offer, you know, Network as a service.”*

Additionally, SDN supports new business models—such as NaaS and on-demand bandwidth provisioning—that allow ISPs to deliver more flexible, customizable services. Participant 10 (C, L2) envisioned: *“I think we, you know, we on the way to being in a position where you know a **customer can log on to a portal** almost like an “Cloud Provider A” orders service, and they will be very little human interaction.”*

Beyond cross-domain service orchestration, SDN's northbound APIs enable integration with advanced technologies like AI and ML. Participant 4 (A, L3) explained: *“I can take with AI and all that changes that, more of the things that we are struggling with, will get a little bit more simplified with the AI assistance or even suggestion of how to deploy things. **Troubleshooting** now we have to go and click might find out in future you just have to enter the service automatically this thing will go and figure out if the problem there is and give you the solution.”*

## Social Challenges Influencing SDN Adoption

### *Knowledge Gaps and Training Needs*

Network professionals often feel that SDN is thrust upon them with inadequate training and support. Participant 3(P, L3) stated: *“Seems like obviously **knowledge is the biggest problem** for SDN*

currently and getting the proper knowledge would obviously make things better in terms of, how things are.”

Reinforcing this observation, Participant 1(A, L2) described the lack of preparation: “So from beginning to end, it was quite a **learning curve**. I would say that there was a lot of people that didn't understand. The technology, the way it was introduced to the network, was more this is the **new product that the customer wants. Figure it out.**”

### **A New Way of Thinking**

Beyond basic networking knowledge for SDN, network professionals must learn new skills to fully leverage SDN's benefits. Participant 4(A, L3), a DevNet Engineer (Automation), emphasized the importance of understanding APIs and programming: “**They must be trained to use APIs**, coz I believe all of these SDNs, SDN, whatever automation. The entry point is APIs. If you don't understand how to use APIs, you won't see the benefit of this SDN automation and whatnot; the same way as you back then, if you didn't know how to use CLI, there was no way you can interact with devices, so I think. An organisation need to understand that people need to learn how to interact with APIs. They need to enable engineers or to write scripts, yeah, learn Python. I think Python APIs, you should be, if an engineer, they should be forced to learn those things.” This need for new skills reflects a broader shift in the mindset required for SDN. SDN requires **moving from a device-centric view** to a systems-thinking approach encompassing controllers, APIs and the entire network as a programmable entity. It was further explained: “Without the knowledge of APIs, it's gonna be hard cause **you'll only just be a click person**. You wouldn't know how to integrate with these systems and get more information.”

### **Skill Erosion**

The increased automation offered by SDN can lead to skill erosion among network professionals. Participant 10(C, L2) observed: “You know, we all human beings, and we all do our working and knowing. And if everything is sort of done for you it's that situation of you **use it or you lose it**. Adding to this concern, he later stated: “I find that **there's sort of a skills drop**, and it's really because, you know, we've automated this in such a way that it's next finish, and you deployed your service to end.”

Participant 4(P, L3) expressed a related concern: “As we move to this SD-WAN world [talking about all SDN solutions], we **tend to forget the fundamentals**. We think everything since it's SDN or it's GUI or whatever, we don't really need to care about the roots or our packet flows or the small things that you need to know as a network engineer...we're losing that.”

He later warned of role degradation: “We no longer think as network engineers; we think as administrators, not even administrators, as operators. **We are no longer network engineers; we just click-click**; we don't care if it works after that. If it works, it works we don't care. So, I think the challenge is there whereby we're losing that, that skill, even though even myself click, click. If somebody did design something and say this is how it works, I forget that, oh, behind the scenes, this is actually the basic routing that I know that is happening behind the scenes, so, when it fails, I need to go back to the fundamentals”

He further explained why this transition is good for both career growth and the company: “If you have knowledge of using APIs and writing scripts it will **amplify your career**, and it will make you **more valuable to an organisation** than just being a person who clicks, and don't know how to integrate with the systems themselves.”

Adding to the potential negative consequences of skill erosion, Participant 7(C, L3) also raised the potential for job displacement: “There's a **risk of, you know, employment**, you know, either that or then people need to upskill, you know. I don't know, people are not upskilling quick enough, you know, and this the risk for me is SDN almost is going to, yeah, it's going to **affect employment generally**. You know, in countries where employment is, unemployment's already high in my opinion. You know, if it's done properly or then we need to just ensure that that people upscale quick enough, you know. Maybe we just need to upskill quick enough.”

## Culture of Learning

Learning new skills and solving problems should be encouraged across all teams. Participant 1 (A, L2) pointed out that some departments embrace challenges; whereas others avoid them: **“Certain departments see a problem, and they automatically know OK, but we have a solution for this, or let's build a solution. Where other people say, but this is a bit complicated; can someone else do it, or team x hasn't showed me how to do it...We would see some negativity with the culture of saying, but this is something new. We didn't have training on this, or it's something new. I don't understand this or why should a customer move to it.”**

Creating and fostering a learning culture is crucial when transitioning to SDN. Network professionals need to get excited about the new era of networking, as Participant 10(C, L2) emphasized the importance of generating enthusiasm: **“I think you need to generate excitement for it, right? And I know sometimes, you know, for you and me, networks are exciting and whatever. But to 90% of you know our customers, which are IT professionals, networking isn't sexy, right? You know, cloud is, you know, high-end firewall, high-end server, you know AI, you know, all of these things is sexy and its the new hotness and networking is just, you know, the road to get to there.”**

Organizations must create a supportive and collaborative environment that enables experimentation and skill development, allowing network professionals to learn by seeing and doing. To foster a supportive environment that enables experimentation and skill development, Participant 1 (A, L2) recommended:

**“I think the root cause is not being traced, and that's basically either skill sharing or knowledge sharing for the advantages, and not just saying, but oh, it's a huge advantage for your network. You need to showcase those enhancements or how it can improve the network.”**

Similarly, Participant 5(S, L1) suggested to: **“host more workshops, get more people involved, hands-on. Give them the resources they would need and promote it in a way that it will look like an advantage and not another challenge.”**

## Resistance to Change and Change Management

SDN also brings resistance to change. Participant 10(C, L2) observed: **“There's also a lot, and I think unfortunately, you know there there's a culture where a resistance to the future of, you know, which is software-defined X...There's some engineers that are just, you know, old school and, you know, viewing this thing as this is going to replace me. And, you know, that's obviously, you know, some flawed logic there, but that's the reality there. There's the guys that, you know, still will conf t (configuration terminal) even if you could touch 100 devices in 15 minutes, they will, you know, over the course of three weeks touch those hundred devices, you know themselves”**

One way to help manage change is through strong leaders, as Participant 2 (A, L1) explained: **“People are resisting it, and a lot of it is just having that patience and having enough leaders to help people slowly streamline into the renewed technologies that we're introducing them to.”**

Organizations need a clear strategy around change management and getting network professionals on board. Several participants (Participant 1(A, L2) mentioned that: **“deploy it (SD-WAN) for the customer instead of ensuring that all the engineers that works with this specific technology understand on how to use it, what's the benefits of it and how it really works.”**

Participant 8(S, L2) shared a similar experience: **“when SD-WAN was introduced, there was no proper training or timelines communicated to the teams we just knew. Yes, SD-WAN is coming and then. One day, we just woke up. We had one client on SD-WAN, and we had to, like, take it up from the with no background, no training. We were not ready prepared for it.”**

The need for vendor-specific, hands-on training was highlighted by both Participant 6 (P, L2) and Participant 3 (P, L3), respectively. Participant 6 suggested:

**“It will be great to have, like, proper training that's also involve, you know, lab environment. So that we can be hands-on because in also with in terms of implement implementation as well.”**

Participant 3 added: “There's been **limited resources** in terms of the knowledge base that was going out into training, the guys for the required technology, and also in terms of **planning and understanding how the SDN gets roll out** to how the SDN for each of the different **vendors gets rolled out differently and the standardisation of that as well so.**”

Organizations must actively involve their network professionals in the transition. Participant 5(S, L1) explained: “For the new technologies, the biggest thing that I see is **people's fear of change** and not knowing. So welcoming people in getting them involved and allowing them to actually find their way on their own pace, and not just, how do I put it, put it in their face and say you've gotta deal with it. That would allow for a better adoption.” He also added: “if the organisation can allow us **more freedom into exploring the technology and allowing the people to get more involved**. Not necessarily with the deployment, but have our **voices heard** and questions answered, I think that would create a lot better understanding and acceptance.”

## Social Enablers Influencing SDN Adoption

### Perceived Cost-Effectiveness

Cost reduction on operational work typically goes down with SDN. Participants 7(C, L3) and 10(C, L2) both mentioned cost reduction due to efficiency gained and potentially needing fewer employees, respectively: “We benefit in terms of **cost reduction**, you know. Being more efficient as businesses, but then it also is going to eliminate, you know, jobs” and “the benefits is generally your cost goes down, right, I mean, just if you, if you look at it from “company X” perspective, it's going to be a heck of a lot cheaper, right? I mean, you've even seen this with the, you know what your team does, the orchestration or the “Technology C” orchestration layer, right?”

Looking ahead, Participant 10 envisioned a future with significantly reduced staffing needs: “We're working towards having that as a solution, right, where you know maybe **there's five of engineers looking after everything.**”

### Vendor Relationship

Organizations rely on strong vendor support for technical expertise, software updates, and reliable support to ensure a smooth transitioning and implementation process and ongoing maintenance. Participant 10(C, L2) highlighted the importance of vendor support:

“What's really great is I find in an SDN world there's a lot **more support from the vendor** just in terms of. You know, cadence of updates and especially in today's you know, cyber conscious world, I think it's I think it's a really good thing.”

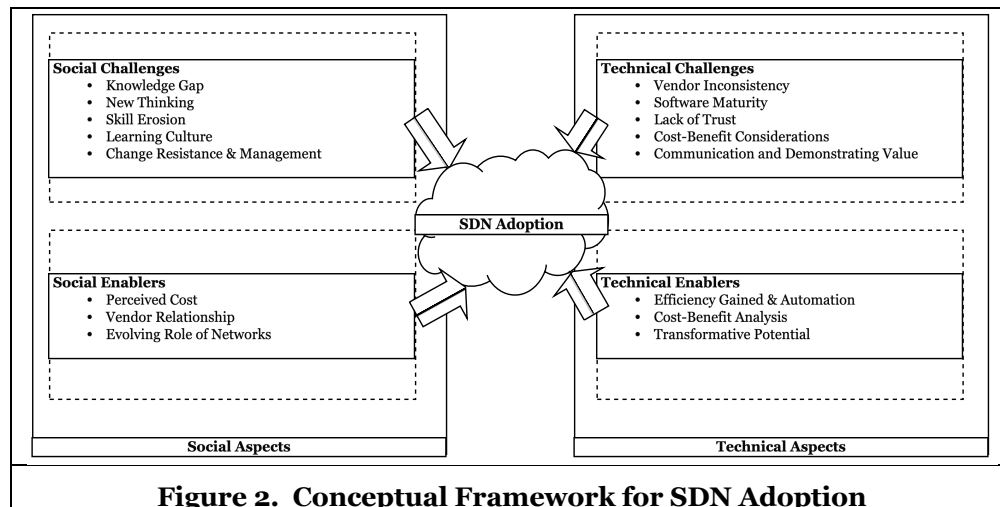
### Evolving Role of Network Professionals

As noted before, network professionals must evolve and learn new skills. Participant 4(A, L3), who has already made this shift, explained why it is beneficial and how it creates new opportunities:

“We're more like becoming system engineers like the video you sent the other day of, which is true we are network engineers, but we no longer considering those. Where we're **no longer thinking the same way as we used to think five years back**, we now think about integrations, APIs and all that of, which is opening more doors for us. The fact that I know how to interact with APIs **doesn't really mean I have to know to interact with network devices**. I can interact with any systems now, any system, and that was something that was limited to us as network engineers back then; we had to care about CLI and all that. But now we are given a chance to actually know about applications.”

## Discussion

We synthesize the findings presented above into a conceptual framework that shows the sociotechnical dynamics of SDN adoption within ISPs (Figure 2). This framework captures both technical and social factors, providing a holistic view of the challenges and enablers shaping the adoption process in organizations.



First, the adoption of SDN faces several social challenges. Network professionals often feel unprepared due to inadequate training and the complexity of vendor implementations. SDN requires a shift from device-centric to systems-thinking, emphasizing the need for new skills like understanding APIs and programming. This transition can lead to skill erosion and job displacement concerns. A culture of learning and experimentation is crucial, but resistance to change persists, often due to fear and lack of proper change management. Organizations must foster a supportive environment, provide hands-on training, and actively involve network professionals to ensure successful SDN adoption.

Second, the adoption of SDN is influenced by several social enablers. One key factor is perceived cost-effectiveness, as SDN can reduce operational costs and staffing needs due to increased efficiency. Strong vendor relationships are crucial, as well as providing technical expertise, software updates, and reliable support. Additionally, the evolving role of network professionals, who must learn new skills like API integration, opens new opportunities and shifts their focus from traditional networking tasks to broader system engineering roles. This evolution is seen as beneficial for both career growth and organizational efficiency.

Third, technical challenges influencing SDN adoption include vendor inconsistency, software maturity, and reliability issues. Network re-architecture is often required by SDN solutions, leading to planning difficulties and integration challenges. Inconsistent operations are caused by vendors' diverse backgrounds. Common software bugs are introduced as vendors rush to add new features. The stability of traditional networks is not yet matched by SDN, and high upfront costs are seen as a hindrance. Effective communication of SDN's value proposition is deemed crucial to justifying the investment and encouraging adoption.

Fourth, SDN adoption is driven by several technical enablers. SDN enhances efficiency and automation, with user-friendly GUIs simplifying operations. It enables service orchestration and provisioning, supporting the Network as a service model. SDN solutions, like Software-Defined Wide Area Network (SD-WAN), offer cost benefits and flexibility, reducing reliance on expensive Multiprotocol Label Switching (MPLS) connections. The transformative potential of SDN includes cross-domain service orchestration and integration with AI and ML, allowing for advanced automation and troubleshooting. These capabilities help ISPs offer more flexible and customizable services with minimal human intervention.

Together, the technical pillar encompasses both technical challenges and enablers, while the social pillar includes social challenges and enablers. Both pillars operate within the ISP operations environment and significantly influence SDN adoption. The model underscores the necessity of a holistic approach that integrates sociotechnical perspectives, including social, technical, and environmental factors. This model contributes to a deeper understanding of these elements by examining the lived experiences of network professionals within a large African ISP, thereby providing valuable insights for both practitioners and researchers. The findings emphasize the importance of adopting a sociotechnical perspective on SDN

adoption, recognizing that successful implementations require addressing both technical and social challenges.

## **Conclusion**

The adoption of SDN represents a pivotal shift in how ISPs manage and operate their networks in an era defined by rapid technological advancements and escalating digital demands. This study has illuminated the complex interplay of sociotechnical factors that influence SDN adoption, offering a comprehensive framework that integrates both technical and social dimensions. On the technical front, while SDN introduces transformative capabilities such as enhanced automation, scalability, and cost efficiency, it also presents challenges like vendor inconsistency, software maturity issues, and high upfront costs. These challenges underscore the need for ISPs to carefully evaluate SDN solutions, prioritize standardization, and effectively communicate the value proposition of SDN to justify investments.

Equally critical are the social dimensions of SDN adoption. The transition to SDN necessitates a cultural shift within organizations, requiring network professionals to move from device-centric thinking to systems-oriented approaches. This shift demands new skills, such as API integration and programming, and highlights the importance of fostering a culture of learning and experimentation. However, resistance to change, skill erosion, and inadequate training remain significant barriers. To overcome these challenges, ISPs must implement robust change management strategies, provide hands-on training, and actively involve network professionals in the adoption process. By doing so, organizations can mitigate resistance, build confidence, and ensure a smoother transition to SDN.

The findings of this study emphasize that SDN adoption is not merely a technological upgrade but a sociotechnical transformation that requires a holistic approach. ISPs must balance technical feasibility with organizational readiness, addressing both the human and technical aspects of implementation. By leveraging the enablers—such as cost-effectiveness, vendor support, and the evolving role of network professionals—while mitigating the challenges, ISPs can unlock the full potential of SDN to create more agile, efficient, and future-ready networks. The findings are context-specific and may not be directly generalizable to smaller ISPs, which often face different resource constraints and organizational structures. Similarly, ISPs in other geographic regions may operate under distinct regulatory frameworks and market conditions, which could influence SDN adoption differently. Additionally, the study's focus on a single ISP with a specific networking infrastructure limits its applicability to organizations with different technological architectures. Although the chosen ISP is a significant player in Africa and has implemented multiple SDN solutions, the findings represent a snapshot of a rapidly evolving technological landscape. Furthermore, the study's qualitative nature introduces the potential for researcher bias, despite mitigation strategies. These limitations highlight the need for caution when extrapolating the findings to broader contexts.

Future research should address these limitations and explore emerging opportunities in SDN adoption. One promising direction is the investigation of the evolving role of network professionals in SDN-enabled environments, particularly the shifting skillsets and responsibilities required to manage these advanced networks. This could inform the development of targeted training programs to bridge skill gaps and prepare the workforce for the demands of SDN. Additionally, the integration of artificial intelligence (AI) and machine learning (ML) with SDN architectures presents a fertile area for exploration. Research into how AI and ML can enhance network automation, optimization, and security could unlock new possibilities for intelligent and adaptive network infrastructures.

Finally, this research contributes to both academic and practical domains by providing a deeper understanding of the sociotechnical dynamics shaping SDN adoption. For practitioners, it offers actionable insights into navigating the complexities of SDN implementation, from training strategies to change management. For researchers, it highlights the need for further exploration into the evolving role of IT professionals and the long-term impacts of SDN on organizational structures and workforce dynamics. As the networking landscape continues to evolve, adopting a sociotechnical perspective will be essential for ISPs to remain competitive and responsive to the ever-changing demands of the digital age.

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