ADOPTING SMART METERS TECHNOLOGY AMONG DOMESTIC CONSUMERS IN CEYLON ELECTRICITY BOARD

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Abstract

The immense increase in the electricity demand has created a crisis in Sri Lanka, particularly during the night-time peak. Demand-side management is a strategy used by electricity utilities that aims to persuade consumers to alter their energy consumption behaviour during peak times, and energy monitoring is therefore crucial to the success of this effort. Due to poor monitoring capacity and lagging behind the regional technological norms, the Sri Lankan context made it necessary to introduce smart meter technology among domestic consumers. The study focuses on identifying the prospective barriers and bottlenecks for the implementation of identifying the barriers and bottlenecks for implementing smart meters in the Ceylon Electricity Board (CEB). The exploratory qualitative case study method was used as the study design, and primary data was collected by conducting semi-structured in-depth interviews. The study sample comprises 12 industry experts from CEB and the regulatory body. Thematic analysis is used as the primary data analysis tool. Inconsistency of national policy, poor IT Infrastructure, lack of top management contribution, regulatory barriers, financial restraints and organizational culture were revealed as significant barriers to the results and further categorized into three dimensions: technological, organizational and government involvement and policy support. The study highlights the importance of presenting reliable and accurate data and statistics to establish government policies, increase individual job engagement, develop a performance-oriented culture and collaborate with information industry institutions.

Keywords: Demand side management, energy crisis, prospective barriers, smart meter implementation.

1. Introduction

Electricity is pivotal in modern society, underpinning value-added systems and driving economic development. Access to electricity is inextricably linked to prosperity, serving as the third key determinant of production. Amidst the global energy crisis, non-conventional renewable energy sources, energy conservation, and demand-side management strategies have emerged as viable solutions.

Sri Lanka's electricity sector is grappling with a dual crisis – energy shortages and financial constraints – necessitating an efficient management overhaul of the existing system. Optimizing domestic energy demand and fostering voluntary energy reduction initiatives are critical for economic revitalization. Voluntary energy reduction stands out as a pivotal strategy for Sri Lanka to effectively address its energy expenditure, elevate its environmental performance, and reinforce its energy security.

Instead of resorting to piecemeal solutions, a comprehensive demand-side management system coupled with behavioural changes aimed at promoting voluntary energy conservation is essential. Implementing DSM programs that incentivize consumers to curtail their electricity consumption during peak hours can alleviate grid congestion and lower overall demand.

However, inherent drawbacks within the Ceylon Electricity Board (CEB) hinder the widespread adoption of these measures.

1.1. Research Problem

Sri Lanka's current energy and financial woes have highlighted the urgent need for efficient management of the existing energy infrastructure. In this regard, optimizing domestic energy demand, which currently remains largely untapped for economic productivity, presents a critical strategy for fostering economic growth. Concurrent with this, encouraging voluntary energy reduction among the general public and institutionalizing such practices are essential steps. However, achieving these objectives requires the establishment of an effective demand-side management system within the domestic sector.

The current demand-side management (DSM) paradigm within the Ceylon Electricity Board (CEB) has not gained widespread traction due to several critical limitations. Foremost among these is the inadequate monitoring capability to effectively implement DSM strategies. The existing metering infrastructure lacks the granularity to track real-time demand variations based on time of day, purpose of energy consumption, and other relevant parameters. Furthermore, the dissemination of DSM information to consumers remains limited, hindering the effectiveness of demand reduction initiatives. The CEB's current communication channels are inadequate in reaching a broad audience and providing tailored energy-saving recommendations. Additionally, the lack of incentives for consumers to participate in DSM programs further impedes the overall effectiveness of these initiatives.

In light of these challenges, the research problem at hand centers on identifying and resolving the barriers hindering the implementation of effective DSM within the CEB. By addressing these limitations, the CEB can effectively harness the potential of DSM to reduce energy consumption, optimize grid operations, and enhance overall energy efficiency.

1.2. Objective of the Study

The overarching aim of this study is to uncover the key obstacles impeding the successful integration of Smart Meter technology. Specifically, the research centers on discerning the most impactful hindrances encountered in the implementation of Smart Meters within the CEB (Ceylon et al.) context, while delving into the underlying causative factors responsible for these challenges.

1.3. Significance of the Study

Sabaragamuwa province has a 10:1 ratio (CEB Assist database) between analogue and digital meters, with 10% switching to digital technology and 90% using manual systems. This weakness can be transformed into an opportunity by eliminating intermediate technology costs and implementing smart metering.

Developing standards and policies ensures efficient, cost-effective power supply for stakeholders, including the Ministry of Power and PUCSL, while enhancing transparency in handling inquiries and complaints.

CEB benefits from this study, as it reduces background preparation for technology-related initiations like automated networks and call center operations. The study also assesses the future benefits of implementing key components of a smart grid for real-time demand adjustments.

2. Literature Review

The long-term objective of any electricity utility is an energy-sufficient nation. By definition, energy sufficiency involves reducing the consumption of energy services to minimize the associated environmental impacts. This may either be through individual actions, such as reducing car travel, or through reducing working time, income, and aggregate consumption (‘downshifting) (Sorrell et al., 2020).

2.1. What Is Demand Side Management (DSM)?

According to Mahdi (2015), Demand side management (DSM) can be defined as modifications in the demand-side energy consumption pattern to foster better efficiency and operations in electrical energy systems.

2.2. Why is DSM Important?

DSM has reformed the traditional mode of thinking to construct a new power plant to meet the demand. DSM optimizes the consumption manners and improves the terminal power consumption efficiency, and it can not only fulfill the same power consumption function but also decrease the energy demand. DSM is a strategy to save energy, reduce consumption, and improve the environment. DSM is an essential tool for enabling more efficient use of available energy resources (Parveen, 2012).

2.3. Necessity of Monitoring Capability on DSM

According to Nguyen (2015), real-time monitoring has become a critical part of distribution network operations, enhancing control and automation capabilities.

Shaikh (2014) primarily argues the purpose of every load monitoring is primarily to facilitate the conservation of energy by taking energy efficiency measures like using less energy consumption devices, using the appropriate timing of appliance usage, and eliminating unwanted energy activities.

2.4. Improving Monitoring Capacity

Installing smart metering infrastructures improves the accounting of the use of energy. Smart meters can help using consumers and utilities understand how each consumer uses electricity (Kulkarni, 2012).

DSM is one of the methods of energy efficiency in an intelligent grid that uses improved materials like a smart meter and advanced metering infrastructure, i.e. at the side of the customer. Additionally, this function enables customers to know how much and helpful energy consumption is and adjust to using the amount of energy. Thus, reshape the load profile and reduce the cost (Palensky & Dietrich, 2011).

The advanced metering infrastructure (AMI) equips each customer with a smart meter, whose basic function is to gather the energy consumption status and upload the information to the control Centre (also known as the power distributor or service provider). A smart meter is also capable of receiving control information (e.g., price and tariff bills) from the control center. Such a two-way information exchange is assumed to be near real-time ultimately (Gharavi & Xu, 2012).

2.5. Rationale for Selecting Domestic Customers for DSM

According to McKenna (2013), compared to the industrial or commercial sectors, the residential sector has a considerably greater number of individual consumers with a relatively small load per individual, offering cost-effective opportunities with low investment needs.

2.6. Best Practices of Smart Meter Implementation

Italy was one of the first countries to develop a smart metering infrastructure. In Italy, Enel, the main Italian DSO (Distributed System Operator) and the third largest energy provider in Europe, have begun deploying smart meters to about 27 million consumers in what is the world's largest smart meters deployment project.

Indonesia is facing a shortage of energy to meet the needs of a developing economy. In addition to improving the existing energy supply system and researching renewable energy, a smart grid is currently considered a potential solution to cope with the power crisis. The findings of the study enhance understanding of consumer perceptions and behaviours and can help decision-makers and energy utility companies develop policies and strategies for a ''one-size-fits-all'' program related to smart meter applications in future residential buildings.

For **Portugal**, the first study indicated positive results; however, due to severe economic challenges, Portugal decided to review the original findings and considered the analysis inconclusive, also refraining from the ambitious 80% target of the EU (ICCS-NTUA & AF Mercados EMI, 2015).

A utility in **Ghana** piloted a non-technical loss reduction program in 2019 to replace postpaid meters with anti-tamper, anti-fraud, and anti-theft smart prepaid meters. By using customer-level residential billing panel data from 2018 to 2019 obtained from the utility. On average, the results indicated that the reported amount of customers' monthly electricity consumption increases by 13.2% when any tampered postpaid meter is replaced with a smart prepaid meter, indicating the NTLs (Non-Technical Losses) by customers.

In **Taiwan**, smart grid development started when the "Smart Grid Master Plan", drafted by the Bureau of Energy (BOE), Ministry of Economic Affairs (MOEA), was approved by the Executive Yuan. The government plans to invest over 4 billion US dollars in 20 years. As directed by the "Smart Grid Promotion Team" of the MOEA, Taipower, which is the largest energy company in Taiwan, is implementing and promoting practices that contribute to the development of the Taipower smart grid. The three stages of development are;

1. Short-Term Early Infrastructure (2011–2015)
2. Middle-Term Further Spread (2016–2020)
3. Long-Term Extensive Application (2021–2030).

As of the end of 2011, Taipower completed the installation of Advanced Metering Infrastructure (AMI) meters for 1200 high-voltage customers (Burea of Energy – Ministry of Economic Affair of Taiwan 2012, Taiwan Power Company2013, Taipower Company, 2013)

The **Korean** government has taken three steps in smart grid development.

1. The announcement of the national smart grid vision in 2009.
2. The release of a national smart grid roadmap in 2010.
3. The launch of the Smart Grid Test on Jeju Island in 2009.

The Ministry of Knowledge Economy (MKE) plans to distribute 10 million units of AMI (one for every two homes) by the year 2016. Also, in 2012, it became mandatory to install highly efficient lighting, such as LED in underground parking lots for apartment buildings. Korea will also implement policies for providing AMI in all households by the year 2020 (Energy Korea, 2016).

The **Vietnam** government has taken steps to implement new smart grid and smart meter technologies. In 2012, Decision No. 1670/QD-TTg by the Prime Minister of Vietnam approved a smart grid development scheme for Vietnam. Accordingly, the scheme will be implemented in three phases (Meet-Bis Project et al., 2013).

2.7. Barriers and Bottlenecks

Organizational factors influencing innovation have been studied both conceptually and empirically. A wide range of organizational determinants of innovation adoption has been identified and tested, such as firm size, financial resources, technical skills, centralization of management functions, top management support, and the presence of change agents or champions for a particular technology (Damanpour, 1991; Tornatzky & Fleischer, 1990; and Zhu et al. 2004).

Innovation decisions by organizations are not necessarily based on a purely rational process in which costs and benefits are weighed and acted upon. Instead, decisions may be partly path-dependent, driven or constrained by the cumulative effects of previous decisions and the organizational structures and culture built over time (Rycroft & Kash, 2002). Most utilities are mature organizations, but significant differences in size, ownership form, and corporate history (e.g., mergers, acquisitions, divestitures) might lead to different adoption outcomes.

Implementing intelligent grids will require additional investment and financial reserves for the smart grid technology transfer, provision of adequate infrastructure, communication systems, hiring of skilled professionals (engineering and other professionals), R&D work and integration with renewable energy sources. However, the payback period is relatively long compared to a high initial investment (Alto & CA, 2011).

Additional infrastructure will be required to deploy and operate smart grid technologies. The smart grid may be understood as modern electric power grid infrastructure for improving efficiency and reliability through automated control, high power converters, modern communications infrastructure, sensing and metering technologies, and modern energy management techniques based on the optimization of demand, energy and network availability (Gungor, 2012)

Power utility-related policies and procedures may be framed to innovative ensure compliance with legislative or regulatory requirements for the implementation of smart grid technologies (Yan, 2013).

2.8. Identification of Literature Gap

Smart meter rollouts have become mandatory in many countries, serving as demand-side solutions and technical transitions. Many and concerns research studies were focused on social factors such as public acceptance, and privacy concerns, and impact on vulnerable populations. Sri Lanka focusing on controlling demand through DSM to manage generation capacity and promote energy conservation attributes among the general public. The successful implementation of smart meters is contingent on overcoming several critical challenges, particularly in Sri Lanka.

Sri Lanka's experience with intelligent meter implementation is relatively incipient, with limited empirical data and information from previous studies or pilot projects. This paucity of knowledge hinders informed decision-making and hampers the identification of potential roadblocks. The limited sharing of information from pilot projects further impedes the collective learning process and hinders the development of effective strategies for successful implementation.

The study will use secondary data from best practices and industry experts to identify the prospective barriers.

3. Methodology

3.1. Study Design

This exploratory qualitative case study investigates barriers and bottlenecks in implementing intelligent meter technology in CEB. It begins with a literature review, focusing on theories, a systematic review, and in-depth interviews with industry experts, professionals, and regulatory bodies.

3.2. Study Approach

3.2.1. Data Collection

Qualitative data collection is usually dependent on interpretation. This means that the data requires several explanations. This is because vast amounts of qualitative evidence are often collected. Additionally, there is no distinction between data collection and its analysis (Cassell & Symon, 1994)

3.2.2. Primary Data Collection

Primary data were gathered from industry experts in CEB and related institutions through in-depth semi-structured interviews.

3.2.3. Population

The population for this analysis included managerial-level executive officers in the distribution sector from various strata. Different levels of authority are represented by the strata that were chosen, such as senior executives, mid-level managers, and junior managers. Strata is once again classified into clusters such as procurement, planning, implementing and operation management, etc.

3.2.4. Sample

Participants were free to express opinions in-depth, asking questions and using interview prompts. Interviews were conducted with experts from diverse sectors and hierarchical levels via Zoom meetings in November 2022. An email was sent to participants to prepare for the interview.

The interview participants were selected via a **non-random convenience** sampling method. The study conducted interviews until theoretical saturation (Sandelowski, 1995; Strauss & Corbin, 2008).

The choice of semi-structured interviews was further due to their significant interpretative power, which gave study informants the necessary freedom and flexibility to communicate their ideas and beliefs (Bryman & Bell, 2003).

Interviewees were selected to collect the appropriate data, views and suggestions from the utility perspective. The data collected through the interviews enable a thorough understanding of prospective barriers from different perspectives and a better assessment of them. Also, the opinions to convert restraining forces into driving forces and get knowledge about the previous mistakes and lessons learned to take preventive actions from the expert point of view.

3.2.5. Development of Interview Questionnaire

Semi-structured questions related to objectives and unstructured ones were asked to approach study findings as depicted in Table 1.

Table 1: Interview Questionnaire

	Question	Objective
1	What is your perspective on the current crisis regarding domestic consumption behaviour in Sri Lanka?	Approach to the current issue, awareness of it, and the sense of urgency to address it and to emphasize the need for change.
2	Among the viable solutions are building new power plants, load-shedding practices, and improving DSM, which should be prioritized according to your opinion?	To understand the need of managing existing resources with the least possible cost.
3	What is your opinion on migrating to Smart Meter-associated infrastructure as an advancement of DSM? ● Importance ● Urgency ● Usefulness and practicality ● Perceived Benefits	To understand the potential of attitudes, willingness to accept the change and how they foresee the future benefits.
4	What type of policy decisions/ corporate decisions need to be established? ● To include this adoption to the energy policy of the country ● To include this adoption in corporate strategy	To know that the Government measures are adequate? How to convince the requirement and build up a national policy to address the issue? How to line up the organizational set-up to make this project successful?

	● Action plan for preliminary initiations	
5	What type of actions are to be taken to? ● Alignment of staff ● Delegation of Authority ● Create change agents within the organization	How to create a vision and communicate it, how to create a powerful team with a good mix and how to empower them.
6	What is the most preferable consumer niche/category for the initial implementation?	Identify how to achieve a more practical and convenient target and the attainable milestones.
7	According to your perspective, what hinders or delays this type of technology adaptation to CEB?	To identify the root causes of delays.
8	What may be the prospective barriers and bottlenecks in each phase of the implementation?	To identify the barriers and their root causes
9	Who will be the pressure groups/what kind of restraining forces could be expected from them and what are the strategies needed to manage/divert or mitigate them?	To identify the restraining forces within the organization
10	Do you have any previous experience with this kind of change interventions/lessons learned, and what is the possibility of utilizing them as driving forces to this implementation?	To identify what are the strategies used in previously implemented change interventions

Source: Author Created

3.2.6. Secondary Data Collection

The secondary data collection was extensive and drew on document analysis. It involved the review of the literature and reports and documents published by power sector utilities of different countries, government policy documents, feasibility studies, annual reports, statistical digests, blogs, road map documents for different interventions and academic journals. The use of these various sources of data allowed for triangulation that enabled the researchers to examine where the data converged and, in turn, provide credibility for the findings (Bowen, 2009; Denzin, 2006).

4. Data Analysis and Results

4.1. Data Analysis

Thematic analysis was utilized to analyze qualitative data from interviews, identifying common themes, topics, ideas, and meaning patterns, and comparing them with replicated data.

The study utilized a thematic analysis process for semi-structured interviews, conducted via Zoom meetings and recorded with consent. Data was transcribed, and microanalysis was conducted to understand overlooked meanings. Codes were defined as the most basic segment, and potential themes were created by analyzing and comparing coded data. Themes were reviewed, defined, and described, and the final analysis was written up.

The findings were used to compare barriers and bottlenecks for Smart Meter technology adoption in the Sri Lankan context with global best practices and benchmarking.

4.2. Primary Data Analysis

Thematic analysis was applied to interview transcripts to identify recurring patterns and frequent responses, dividing content into categories and performing three stages of theme extraction.

1. First Order Themes – Developing descriptive codes
2. Second-Order Themes – Combining descriptive codes as different but closely related categories
3. Third-Order Themes – Linking categorized themes into a theoretical dimension

4.3. Results of Primary Data Analysis

Figure 1 depicts the study's thematic analysis process. To ensure reliability and validity, created themes were cross-checked to determine whether any new themes were appearing or not. The reliability of the analysis was attained once it was confirmed that no new theme was appearing (data saturation).

Figure 1: First, second, and third - order themes of the thematic analysis

Source: Summary of responses given by Thematic Analysis

4.4. Summary of Secondary Data

Secondary data reveals diverse concerns, best practices, and diffusion strategies influenced by country, demographics, political affiliation, leadership styles, and infrastructure development in Sri Lanka.

5. Discussion of the Findings

The recurring patterns found in the thematic analysis allowed six themes to be derived as barriers to the adoption of smart meter technology in CEB and they were lined up in descending order of the degree of significance.

a) Inconsistency of national policy
b) Poor IT infrastructure
c) Lack of top management contribution
d) Regulatory limitations
e) Financial Restraints
f) Organizational culture

5.1. Inconsistency of National Policy

CEB, a state-owned organization, must adhere to legal requirements and adapt to changing national goals and objectives. However, popularity, publicity, and awareness are crucial factors for widespread public understanding of national policies.

Smart meter deployment is highly influenced by government interventions. As explained by Zhou & Brown, (2016) policy measures that address regulatory, financial and social acceptance barriers tend to be more effective in facilitating smart meter diffusion. Recent empirical trends have indicated that it is the government, rather than utilities, which assumes important roles, particularly in the early stage of smart grid development. The national policy framework for smart grids in the US (Executive Office, 2011) and the smart grid vision and tested in South Korea (Mah, 2012) are some examples.
Interviewer emphasized,
"To implement such advancement in CEB, of course there should be some policy decisions. If we recall memories such as "Vidulamu Lanka", it was taken by the government though the inputs are given by CEB itself. As that policy decision was taken by the government or the ministry, they gave huge popularity and publicity to that theme and all the support was given to achieve the objectives."

(Respondent 03)

Having a fixed policy is necessitated since it provides a foundation for all the corresponding actions under that particular decision. Additionally, it will end up as another unsuccessful expedition, whereas experienced in the past. Several respondents have brought up this fact, as shown below.

"Whatever it is, the vision has to be at least fixed for 10 to 20 years. Otherwise, all the plans below the national policy should be changed accordingly. As a utility, we have faced that experience so many times in the past. We planned something and executed different things because of the changes in the national policy. So establishing country-wise policy is crucial, and all other decisions depend on that decision."

(Respondent 05)

"There should be a long-term country policy with a proper cost-benefit analysis of what CEB should do to overcome this crisis, and it should be fixed at least 10 years or so until the outcome is achieved. Unless it should be another incomplete project for CEB."

(Respondent 07)

Government policy inconsistencies cause CEB losses, time, and resources. Learn from global best practices to improve the system.

"Policies should be fixed. What we experienced for a long period is from time to time, from government to government our national policies got changed. Even after working for a few months or years and investing a lot of money, a different new policy comes. So inconsistency is a big problem in going ahead with a particular policy. Most of the developed countries and also the Asian countries like India and China, they fixed the policies and whatever the government comes they go ahead with the existing policies."

(Respondent 10)

National policies serve as crucial instruments for moulding a nation's trajectory and guaranteeing long-term stability. However, when policies are characterized by constant flux or contradictions, public trust in governmental institutions inevitably erodes. This erosion of trust renders it increasingly difficult for governments to effectively implement policies in the future. Furthermore, inconsistent policies foster uncertainty among investors, hindering their ability to plan for the future and ultimately stifling innovation.

In an environment of inconsistent policies, garnering public support for new initiatives becomes a formidable challenge. This lack of support impedes the implementation of reforms and the addressing of pressing issues.

5.2. Poor IT Infrastructure

As explained by Nightingale (2003), smart meters are a more complex technology for incumbent companies than in some previous cases. One reason is that IT hardware, software, and standards are particularly prone to unforeseen complications or incompatibility problems which complicate implementation.

Utility companies must manage large volumes of data and use advanced analytics to convert it into insights for smart meter readings. IT-related applications are crucial in this process. CEB pursued competitive bidding to comply with government procurement guidelines, but the process is complex due to varying data extraction and analysis software. Respondents argue that CEB's current IT capacity is insufficient for this massive task.

"The corporation of our IT unit is inadequate for such a massive implementation. The whole effort may be a waste of time and money if we do not develop our infrastructure to an acceptable level."

(Respondent 07)

"When there are so many interfaces' users will face great difficulty and a lot of time taken for data collecting. When the process itself is a headache, users will not use it. So the main barrier is the infrastructure development after fixing meters."

(Respondent 05)

IT sector development in CEB focuses on smart meters and information system integration for CEB operations. One respondent stated,

"Building the infrastructure should accommodate our whole system and not only this smart meter thing. In that sense, we need a lot of development activities to take place on the IT side. They indeed have to maintain very old and outdated software packages and have very limited resources."

(Respondent 03)

A robust and well-maintained IT infrastructure is a critical foundation for successful smart meter implementation. As Smart meters generate a vast amount of data that needs to be collected, stored, processed, and analyzed. Inadequate IT infrastructure can struggle to handle this data volume, leading to data loss, corruption, or delayed analysis. This can hinder efforts to optimize grid operations, identify energy consumption patterns, and detect anomalies.
Poor IT infrastructure can lead to communication disruptions, preventing smart meters from transmitting data or receiving commands. Also, it has been increased the risk of security breaches, exposing sensitive customer data and compromising grid operations. IT infrastructure needs to scale accordingly to accommodate the growing data volume and communication requirements.

5.3. Lack of Contribution of Top Management

CEB's monopolistic nature creates a less competitive environment, hindering innovation and technology adoption due to limited incentives and technical risks. That is explained in the previous research by (Donaldson & Preston, (1995), as Organizational innovation can be influenced by a range of stakeholders who have an interest in an innovation outcome and the ability to influence that outcome.

Top management plays a crucial role in driving change within an organization. Without their active support, employees may be resistant to adopting new technologies, such as smart meters. This resistance can slow down the implementation process and lead to challenges in integrating smart meters into existing systems. One respondent highlighted,

"Until right now and up to this very moment, we have not seen this as an important thing. There is no particular person or group that delays such a thing. But automatically since we are not foreseen the requirement or benefits, it has been dragged up to now. Now only we are identifying these kinds of avenues."

(Respondent 03)

Another respondent brought up the fact below that people are attracted to and focused on trending technologies without analyzing their compatibility and the degree of compliance with the constraints of the existing system.

"Everyone *is looking at renewable energy and sources, sometimes they are not either educated enough to look at DSM or they just ignore it."*

(Respondent 05)

Sometimes it is all about not working on a proactive basis to prevent future problematic circumstances. Another respondent has stated the fact as;

"CEB has not identified the value of this until the energy crisis became this much crucial. Even though some domestic consumers are asking for a TOU tariff, we are unable to provide it."

(Respondent 06)

Without the unwavering support of top management, the prioritization and allocation of resources for smart meter initiatives can become ambiguous. This ambiguity can lead to delays, cost overruns, and a lack of alignment across different departments within the organization. Top management plays a pivotal role in fostering a culture of innovation by encouraging experimentation, risk-taking, and collaboration. Without their endorsement, the introduction of new technologies, such as smart meters, can be challenging, potentially hindering the realization of their full potential benefits.

5.4. Regulatory Limitations

PUCSL impacted CEB's decisions on raising tariffs and subsidies, causing financial difficulties between 2014-2022. Political pressure prevented CEB from adding implementation costs and obtaining necessary approvals.

"There are lots of restrictions. One thing is CEB is not an independent utility. Because we are bounded by PUCSL, MOPE and other government involvements. Obtaining approval is a big issue"

(Respondent 04)

"As a policy government and PUCSL should identify this as a viable and timely need, and they should allow CEB to add the meter cost to our tariff."

(Respondent 06)

The widespread adoption of smart meters is contingent upon the establishment of robust regulatory frameworks that provide adequate incentives for utilities to invest in the necessary infrastructure. In the absence of clear financial benefits or regulatory mandates, utilities may be reluctant to make the upfront investments required for smart meter deployment, hindering the realization of their potential advantages.

Additionally, the establishment of clear technical standards is essential to ensure seamless integration of smart meters into existing grid infrastructure. Without standardized specifications, smart meters from different manufacturers may not communicate effectively, leading to compatibility issues and integration challenges.

Furthermore, regulatory frameworks must address the allocation of costs and tariff structures associated with smart meter implementation to prevent undue financial burdens on both utilities and customers. Clear guidelines are necessary to ensure that the costs and benefits of smart meters are equitably distributed among all stakeholders, fostering greater acceptance and adoption of this transformative technology.

5.5. Financial Restraint

CEB's electrical network infrastructure is analogue-based, deviating from the proposed digital one. To convert to digital, hardware, software, and costs for installation and maintenance must be purchased. This capital-intensive task is not suitable for the current situation.

"When it comes to the importance, I could say this is the most important proposal that needs to be implemented. Also, it is urgent, but it is not practical at the moment regarding financial affordability as it is a massive implementation.

(Respondent 02)

"Since SM and associated system is capital intensive and infrastructure developmental process and those needs finance."

(Respondent 08)

Implementing smart meters in a challenging financial situation requires cost/benefit analysis, but CEB's persuasive power over fundamental requirements, integrations, and mandatory technological standards makes it a viable option. As stated,

"When it comes to funds allocation, due to the prevailing crisis, priorities go for fuel, medicine, essential foods, etc…However, still, we have the convincing power in there."

(Respondent 03)

Implementing smart meters poses a significant financial challenge for utilities with limited resources. The substantial upfront costs associated with smart meter deployment, encompassing the procurement and installation of smart meters, the upgrading of communication infrastructure, and the development and implementation of requisite software systems, can strain the financial capabilities of these utilities. Consequently, utilities may opt for less expensive solutions that offer limited functionalities or may not be compatible with future technological advancements. This decision to priorities cost-effectiveness over future-proofing can lead to the need for costly upgrades or replacements in the future, further exacerbating the financial burden on utilities.

5.6. Organization Culture

CEB operates as an oligopoly in Sri Lanka's distribution sector, creating fewer competitive environments and high risk due to uncertainty avoidance and a short-term culture. This culture impacts long-term goals and vision achievement.

"Existing organizational culture, structure and top-to-bottom level attitudes may not influence any change intervention. There should be a major transformation in those areas to adopt this type of intervention."

(Respondent 01)

"CEB's main focus is system maintenance purposes rather than energy efficiency initiations. These mindsets should be changed and aligned with the new technology standards."

(Respondent 07)

As explained in the literature, a wide range of organizational determinants of innovation adoption have been identified and tested, such as firm size, financial resources, technical skills, centralization of management functions, top management support, and the presence of change agents or champions for a particular technology (Damanpour, 1991; Tornatzky & Fleischer, 1990; and Zhu, 2004). The same factors were highlighted by the respondents as follows.

"In our Research &Development (R&D) unit and Energy Management (EM) Units, there were key characters who were highlighting the importance and trying to implement this kind of technical adaptation a few years back. But the situation not only in CEB but also in the whole country has not supported that kind of innovative ideas and has not become popular."

Organizations must monitor and respond to external changes and trends to seize opportunities. Strong, cohesive cultures allow people to communicate emotions freely, but rigid formality and adherence to norms can lead to similar views and ideas. Controlling cultures restricts innovation and discourages original thought, as revealed by a few respondents.

"Also, to a certain extent, due to the formality and the high uncertainty avoidance of the organizational culture would not support this kind of change interventions or taking challenges."

(Respondent 03)

"Attitudes of the employees, as well as the process of implementation, are very important to make success, this kind of implementation. In every aspect, their intention, mindset and attitude should be focused on the project to achieve the expected outcome."

(Respondent 09)

Organizational culture plays a pivotal role in the success of smart meter implementation. By nurturing a culture that embraces collaboration, innovation, and continuous learning, organizations can effectively adopt smart meters and reap their potential benefits of service. The adoption of smart meters often requires innovative solutions to address specific challenges and adapt to local conditions.

A culture that encourages innovation creates an environment where employees feel empowered to experiment, challenge assumptions, and develop creative approaches. This willingness to innovate can lead to the development of tailored solutions that are more effective and efficient for the organization's specific needs.

5.7. Dimensions Created from Third-Order Themes

Barriers identified and discussed as third-order themes in the primary data analysis were further used to create three dimensions.

1. Government involvement, policy support and Regulatory Factors
2. Organization Factors
3. Technical Factors

6. Conclusion

We are currently dealing with an energy crisis as a nation. Demand Side Management is a quick fix that promotes energy conservation attributes and ought to be a continuous process mandated to be accustomed among the general population. The existing monitoring capacity of the utility on consumer load variations is not sufficient for DSM initiatives.

Smart Meter-associated AMI technology improves monitoring capabilities and impacts parties and empirical aspects. However, CEB has not shown enthusiasm or shared vision for adopting this technology, despite perceived benefits.

This study sought to identify the most significant barriers to this technology adoption through the use of successful stories and benchmarking from the global context and the reviews of industry experts from the local context. The results delineate six significant barriers and further categorized them into three dimensions.

To achieve positive government involvement, policy support, and fair regulations, statistics-based informed decisions and cost-reflective interpretations are crucial. A performance-oriented culture and increased job engagement are essential for organizational growth. Collaboration with the Institute of the Information Technology Industry and smart appliance manufacturers and dealers is essential for IT infrastructure implementation.

CEB processes often have well-established systems, but proper tracking of utilization and user activity is lacking. For instance, meter reading facilities aim to minimize errors, time, and cost but lack an adequate system to ensure process launch compliance.

Table 2 depicts the bulk supply meter reading details of Sabaragamuwa province for January 2023.

Data shows 48% of meter readings were manually performed, causing diverted objectives from nearly half of the procedure. Factors like inadequate system evaluation, job engagement, comprehension, and knowledge should be considered before implementing a capital-intensive project.

Table 2: Bulk Supply Meter readings in Sabaragamuwa Province – January 2023

Area	Total No of Bulk Supplies	No. of Remote Readings	No. of Manual Readings
Ratnapura	152	129	23
Eheliyagoda	102	36	66
Kahawatta	144	90	54
Embilipitiya	103	21	82
Ruwanwella	103	37	66
Total	604	313	291

Source: Prepared by the researcher using the data extracted from the official MIS of the CEB

Leadership and unique understanding can impact CEB processes, requiring the development of unique methodologies, instructions, and guidelines to eliminate anomalies and positively impact the organization. This clarity provides direction for employees and ensures that their efforts are aligned with the organization's overarching objectives. Leaders empower employees to take ownership of CEB processes by encouraging their participation in process design, implementation, and improvement. This empowerment fosters a sense of responsibility and engagement among employees, leading to more effective process execution.a culture of continuous improvement by actively seeking feedback, identifying process inefficiencies, and implementing corrective measures should be cultivated. This commitment to continuous improvement ensures that CEB processes remain relevant, efficient, and aligned with the organization's evolving needs.

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