Journal of System Management (JSM)
Online ISSN: 2783-4190, Print ISSN: 2783-428x
10.82134/sjsm.2026.1211155
12(1), 2026, pp. 127-152

Received: 05/07/2025
Accepted: 28/08/2025

RESEARCH ARTICLE Open Access

Adoption of Soft Systems Methodology (SSM) to Develop an Efficiency Assessment Framework through DEA for Gas-Fired Power Plants in Southern Iraq

Kamil Yaseen Sharrad [1], Payam Shojaei [2]*, Abolghasem Ebrahimi [3], Kazem Askarifar [4]

Abstract
Given the growing demand for electricity in Iraq and the significant contribution of gas-fired power plants to electricity generation, evaluating and improving the efficiency of these units from economic, environmental, and social perspectives is an imperative. This study aims to develop an integrated framework for identifying inputs and outputs for employing Data Envelopment Analysis (DEA) to assess the performance of gas-fired power plants in southern Iraq. To this end, Soft Systems Methodology (SSM) was employed to identify and structure problematic factors and challenges through expert interviews. The challenges of electricity generation and influencing factors were structured as inputs and outputs. The findings revealed that the inputs and outputs of gas-fired power plants in Iraq can be defined within seven subsystems: economic, environmental, supply, human resources, technology and infrastructure, social, and managerial. The integration of SSM and DEA provides an effective framework for multifaceted performance analysis, enabling root definitions and conceptual modeling that support evidence-based policymaking, efficient resource allocation, and strategic planning for structural reform and transition toward sustainable energy within Iraq's power sector.

Keywords: *Data Envelopment Analysis, Soft Systems Methodology, Gas-fired power plants, Iraq's power sector, Performance evaluation*

Introduction

In today's world, energy is recognized as one of the fundamental pillars of economic, environmental, social, and industrial development across nations. Population growth, urban expansion, industrialization, and rising living standards in many developing countries—particularly in the Middle East—have led to a continuous increase in energy demand (Chen et al., 2022; Yumashev et al., 2020). Among various forms of energy, electricity is especially vital; it not only facilitates daily life but also underpins production, transportation, agriculture, education, and numerous other economic activities (Mahfoudh & Amar, 2020; EIA, 2023). According to the International Energy Agency's 2024 report, Middle Eastern countries possess a significant share of the world's energy resources, yet continue to face structural challenges in energy efficiency and management. Iraq, as one of the region's major oil and gas producers, exemplifies this contradiction; despite vast reserves, its

1. Ph.D. Student in Operations Management, Department of Management, Shiraz University, Shiraz, Iran
2. Associate Professor, Department of Management, Shiraz University, Shiraz, Iran (Corresponding Author: pshojaei@shirazu.ac.ir)
3. Associate Professor, Department of Management, Shiraz University, Shiraz, Iran
4. Associate Professor, Department of Management, Shiraz University, Shiraz, Iran

electricity sector struggles with a pronounced mismatch between supply and demand. In 2023, Iraq's maximum electricity generation capacity was approximately 27.4 gigawatts, while peak demand exceeded 35 gigawatts (IEA, 2024). This considerable gap has led to widespread outages, an overreliance on imported electricity, and extensive use of non-standard generators.

Studies indicate that over 98% of electricity generated in Iraq is sourced from fossil fuels—a figure significantly higher than the global average—resulting in elevated greenhouse gas emissions and increased environmental pressure (Ember, 2024). Concurrently, Iraq imports more than 30% of its annual electricity consumption from neighboring countries such as Iran, Turkey, and Jordan, reflecting insufficient domestic infrastructure and the low operational efficiency of its power plants. Moreover, energy losses within Iraq's electricity network are estimated to be extremely high. According to World Bank statistics, nearly 50% of the electricity produced either never reaches the billing stage or remains unpaid by consumers. This situation stems from obsolete equipment, poor distribution management, and the absence of effective pricing policies (World Bank, 2023). Therefore, enhancing the efficiency of power plants and optimizing electricity production have become strategic priorities for the Iraqi government and international organizations. In response to these challenges, the application of quantitative and analytical methods for evaluating and analyzing performance in the power sector appears essential. Data Envelopment Analysis (DEA) is among the most well-established non-parametric tools used to assess the relative efficiency of decision-making units based on multiple input and output variables (Xu et al., 2023). DEA is a mathematical programming technique grounded in a positivist approach that evaluates the relative efficiency of decision-making units using input and output data. This method can effectively compare the performance of various power plants and identify inefficient units. A review of the theoretical literature related to DEA in the energy domain reveals that the model has been applied to assess the performance of thermal, gas-fired, nuclear, and even renewable power plants. The study by Bampatsou, Papadopoulos, and Zervas (2013) on nuclear power plants in Europe; the research by Munisamy and Arabi (2015) on thermal power plants in Iran; Xiao, Tian, and Ren's (2022) decade-long investigation of power plants in China; and the work by Rodríguez-Lozano and Cifuentes-Yate (2021) on electricity generation in the Middle East are notable examples of studies that have employed Data Envelopment Analysis (DEA) in the assessment of power generation efficiency. These investigations collectively demonstrate DEA's capability to identify inefficiencies in energy resource utilization and to assist decision-makers in mapping out performance improvement paths. The findings highlight the necessity of using the DEA model to evaluate gas-fired power plants in a country like Iraq, where infrastructure has been severely impacted in recent years and energy productivity remains under intense pressure from rising demand.

However, quantitative analysis alone is insufficient for comprehending the human, structural, and institutional dimensions underlying inefficiency. Additionally, the selection of inputs and outputs for efficiency assessment is highly influenced by the judgment of decision-makers, which can significantly affect the outcomes. In this context, Soft Systems Methodology (SSM) serves as a valuable qualitative tool for uncovering systemic and societal roots of inefficiency-related problems (Checkland & Scholes, 1999). This approach the ability to be used in identifying indicators, factors, inputs, and outputs and different stakeholders' views through the system structure it follows (Karame et al., 2020; Valafar et al., 2020). At first glance, Soft Systems Methodology (SSM) and Data Envelopment Analysis (DEA) may appear to share limited commonalities—given that SSM is a conceptual framework grounded in subjective epistemology (Mingers, 2009), whereas DEA is a positivist and objectively oriented method. Nevertheless, underlying similarities do exist between these two approaches. Specifically, the transformation process from inputs to outputs serves as the central link in this integrated framework. SSM offers the capacity to provide alternative perspectives on the nature of decision-making units, particularly when considering diverse input and output configurations. In this study, SSM is introduced as a valuable approach for structuring decision-making units and defining relevant inputs and outputs for assessing the efficiency of Iraq's gas-fired power plants using DEA. Through root definition (RD) and conceptual modeling inherent in SSM, a novel pathway is proposed to enhance problem structuring within the DEA framework. Accordingly, this study designs and implements an integrated analytical framework based on Soft Systems Methodology (SSM) to evaluate the efficiency of gas-fired power plants in southern Iraq. Within this framework, SSM is employed to identify key structural and human-related factors contributing to inefficiency, while DEA is applied to assess the relative performance of the power plants using defined inputs and outputs. This approach facilitates the development of improvement strategies both at the technical and systemic levels. Given the growing importance of efficiency in the power sector and its direct impact on economic growth, social equity, and environmental sustainability, such research can play a pivotal role in advancing sustainable development, effective policymaking, and strategic energy planning in Iraq and other developing countries in the region.

Theoretical Framework

Importance of Electricity in Iraq Development

Electricity is considered one of the most critical infrastructures for economic and industrial growth. As a secondary form of energy, electricity can be converted into other energy types and plays a key role across all economic sectors, including agriculture, industry, transportation, services, and education (Dong et al., 2024). Nations seeking greater productivity, social welfare, and international competitiveness are compelled to develop sustainable energy supply systems—particularly in the electricity sector (Adom, 2024). Globally, electricity consumption has risen markedly in recent decades. For instance, in 2019, global electricity usage surpassed 25,000 terawatt-hours (IEA, 2024). Meanwhile, the structure of electricity generation has undergone significant transformation; although fossil fuels continue to account for the majority share (around 62%) of global production, the share of renewable energy sources has grown to approximately 27% (Hassan et al., 2024), while nuclear energy covers about 10% of global electricity output. These figures reflect a gradual global transition from polluting energy sources to cleaner alternatives. Accordingly, with the continued increase in electricity demand—especially in developing countries—precise planning for optimal and sustainable electricity generation has become more critical than ever (Belaid, 2023).

Iraq, as a developing country endowed with vast oil and gas resources, faces serious challenges in electricity generation. Infrastructure damage due to repeated wars, inefficient management, high transmission losses, and reliance on imports are among the major obstacles confronting the country (Mills & Salman, 2020). Iraq's first electricity grid was established in Baghdad in 1917, yet during the Gulf War (1991), over 90% of the grid was destroyed. Although more than 68 new power plants—comprising thermal, gas-fired, and hydroelectric units—have been built since 2003, operational capacity still falls short of meeting the growing demand from population and industrial expansion (Nijkamp et al., 2025; World Bank, 2023). Iraq's electricity is primarily generated from three types of power plants (Worldometers, 2024; IEA, 2024):

- Thermal power plants: Seven active units located in provinces such as Baghdad, Nineveh, and Babylon, with an approximate combined capacity of 6,900 megawatts, operating on fossil fuels.
- Hydroelectric power plants: Eight units based at dams such as Mosul and Samarra with a total capacity of 2,583 megawatts. Their performance is variable and constrained due to declining rainfall.
- Gas-fired power plants: 26 operational stations with a collective capacity exceeding 14,550 megawatts, constituting the primary source of electricity production in Iraq. However, due to technical issues and gas shortages, these plants are not fully utilized.

Despite increased installed capacity, Iraq continues to face a shortfall of 10 to 15 gigawatts during peak consumption periods, and its reliance on electricity imports places considerable strain on the national economy (Ember, 2024). In addition to this issue, high energy losses, the absence of realistic pricing mechanisms, and inefficiencies in management structures are key factors contributing to low productivity. Under such conditions, the use of quantitative and analytical methods—such as Data Envelopment Analysis (DEA)—offers a viable strategy for enhancing efficiency, reducing resource waste, and improving policy decision-making. However, measuring efficiency in the energy sector is inherently challenging and necessitates models that appropriately account for environmental variables such as energy prices, technological capabilities, firm size, and other micro-level factors (Arabshahi Delouee et al., 2020; Li & Tao, 2017; Rahman et al., 2023). Energy efficiency in the electricity industry refers to the generation of electricity with minimal energy consumption and pollutant emissions. This metric considers not only the ratio of energy services to energy inputs but is also influenced by factors such as technology, industrial structure, energy pricing, and consumption patterns (Fu et al., 2023). Therefore, it becomes essential to identify the key structural and human-related factors driving inefficiency and to determine appropriate inputs and outputs for evaluating the relative performance of electricity generation. Through this approach, performance improvement strategies can be proposed at both technical and systemic levels.

Literature Review

In recent years, numerous studies have been conducted to evaluate energy efficiency in the electricity sector through the application of Data Envelopment Analysis (DEA). Among domestic investigations, Mahmood et al. (2017), through an assessment of ISO 50001 standards at Iraq’s Ministry of Electricity, demonstrated that implementation of the standard led to improved performance in power generation units. According to the majority of respondents, its application was both straightforward and effective. In continuation of this research trajectory, Nadhum and Erzaij (2020) examined barriers to electricity generation projects in Iraq and identified economic and financial variables as the most influential factors in this domain. Their mathematical model contributed to prioritization strategies for project design in the country. In other studies, Abed et al. (2020), focusing on energy optimization through smart grids and solar energy in Iraq, found that modern technologies can significantly reduce energy losses. Altai et al. (2022), through a comprehensive analysis of Iraq's electricity sector, emphasized the necessity for structural reforms and proposed measures aimed at improving billing systems, enhancing private sector participation, and increasing overall efficiency.

Extensive research has been conducted in recent years on the efficiency of the electricity sector and the application of Data Envelopment Analysis (DEA). Ervural et al. (2018) applied a two-stage DEA model to thermal power plants with a focus on sustainability. A systematic review by Mohd Chachuli et al. (2020) further shows that Data Envelopment Analysis (DEA) has been extensively used in evaluating the performance of renewable energy sources—such as solar, wind, and biomass—and that the methodological evolution of DEA in recent years has prominently featured dynamic and hybrid models. Guang et al. (2022), through an analysis of electricity consumption trends from 2007 to 2019, attributed the decline in consumption rates to changes in industrial structure and improvements in energy efficiency. They projected that, if this trajectory continues, electricity consumption will become increasingly sustainable in the future. Studies by Mamipour and Najafzadeh (2016), Radsar et al. (2021), and Khosravi et al. (2022), using network DEA approaches and incorporating undesirable outputs such as energy losses and pollutant emissions, have underscored the critical role of power plants, regional electricity companies, and distribution firms in shaping the overall efficiency of Iran’s electricity industry. Patyal et al. (2023) conducted an empirical study evaluating the operational performance of 48 Indian electricity distribution companies. Their research employed a hybrid methodology integrating Data Envelopment Analysis (DEA) and Multi-Attribute Decision Making (MADM) to distinguish between efficient and inefficient DMUs. The study by Esfandiari and Saati (2024) introduced a hybrid two-stage DEA model to enable more precise techno-economic analysis of thermal power plants. Wang et al. (2024), in their evaluation of Total Factor Energy Efficiency (TFEE) across ten major energy-consuming countries, found that developed nations such as the United States and Germany ranked highest in energy efficiency, while China and India exhibited relatively weaker performance. Their analysis further highlighted the significant influence of per capita GDP and energy consumption structure in determining efficiency levels. Wei and Zhao (2024) developed a three-stage DEA model to assess carbon emission reduction performance across 30 Chinese provinces, municipalities, and autonomous regions. This methodological framework effectively controlled for competitive dynamics and external environmental factors, enhancing the robustness of their efficiency measurements. Sufia et al. (2025) applied an innovative three-stage DEA approach to analyze the operational efficiency of Indian electricity distribution utilities from 2016–17 to 2019–20. Their results underscored the critical role of service quality parameters in operational efficiency evaluations. Yadava et al. (2025) performed a benchmarking analysis of Indian electricity distribution companies, revealing that transient inefficiency contributed more significantly to overall inefficiency than persistent inefficiency. Zhang and Zhang (2025) introduced an extended mixed-network DEA framework designed to differentiate between fossil energy power generation (FEPG) and non-fossil energy power generation (NFPG). Their model simultaneously addressed generation diversity, resource sharing, input optimization, and undesirable outputs, offering a comprehensive analytical tool for energy efficiency assessment.

These studies consistently identified the production stage as having the greatest impact on aggregate productivity, and applied both cross-sectional and panel data to analyze temporal trends and performance disparities across units. Additionally, several recent studies have emphasized the crucial role of Soft Systems Methodology (SSM) in identifying conceptual structures and deriving input/output indicators for DEA within the electricity industry. Susanty et al. (2022) employed SSM to develop a structured framework for analyzing the efficiency of a power distribution company.

As evidenced by the review of empirical literature, various studies across different countries—including Iraq—have examined electricity generation efficiency from diverse perspectives. However, analysis of these investigations reveals that most research efforts have focused predominantly on evaluating and measuring efficiency within power plants and electricity production companies, while the development of a suitable model to enhance electricity generation efficiency has yet to become a central focus for researchers. The use of Soft Systems Methodology (SSM), which is grounded in systems thinking, meaning, self-reflection, interpretation, human experience, and learning—alongside tools such as CATWOE and PQR analysis—can provide a rich and nuanced understanding of how inputs are transformed into outputs within the electricity generation system of gas-fired power plants. This approach offers a structured means to accommodate diverse viewpoints and development interests, ultimately supporting efficiency assessment through the identification of appropriate input and output variables.

Methodology

This study seeks to develop a model for evaluating electricity generation efficiency in gas-fired power plants located in southern Iraq, aiming to apply its findings to enhance productivity and reduce inefficiencies within these facilities. The research utilizes Soft Systems Methodology (SSM) to identify the input and output variables associated with the operational performance of gas-fired power stations (Mingers et al., 2009; Susanty et al., 2022). To achieve this, the study combines semi-structured expert interviews, a systematic review of theoretical literature, and consultations with power industry professionals to extract key input and output variables. The research sample consists of specialists from power plants operated under the Southern Iraq General Electricity Production Company, including the Old Khor Al-Zubair, New Khor Al-Zubair, Shuaiba, Nasiriyah, Najibiya, Shatt Al-Basra, Amarah, and Rumaila gas-fired power stations. Table 1 presents the profile of the participating experts. Purposeful judgmental sampling was employed in this study, and data collection instruments included semi-structured interview protocols designed to support the implementation steps of Soft Systems Methodology (SSM). Rooted in systems thinking, SSM offers an interpretive and human-centered approach for addressing complex organizational issues. In this research, SSM was applied to identify appropriate input and output variables for the DEA model through stakeholder interviews and problem environment analysis.

Table 1.
Expert Profile

Affiliation	Academic Degree	Position	Years as Expert
Southern Region Power Production Co.	Bachelor's	Electrical Engineer	22
Nasiriyah Power Generation Unit	Bachelor's	Control Engineer	22
Nasiriyah Power Generation Unit	Bachelor's	Electrical Engineer	22
Nasiriyah Power Generation Unit	Bachelor's	Mechanical Engineer	22
Samawah Power Plant	Bachelor's	Electrical Engineer	9
Samawah Power Plant	Bachelor's	Electrical Engineer	16
Samawah Power Plant	Bachelor's	Mechanical Engineer	6
Samawah Power Plant	Diploma	Technical Manager	20

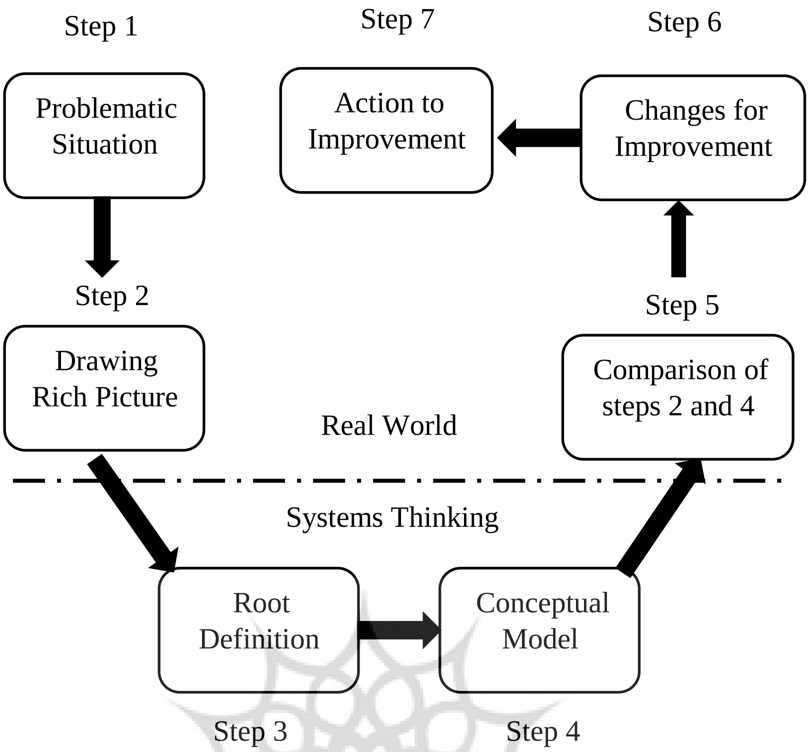
Soft System Methodology (SSM)

The implementation process of Soft Systems Methodology (SSM), as illustrated in Figure 1, comprises seven distinct stages. The first step involves exploring the problematic situation—an initial diagnostic inquiry into the issue environment. This phase includes sessions with managers, operational staff, and analysts to investigate current activities and work practices. It extends beyond identifying explicit problems by adopting a comprehensive and systematic approach to uncover hidden aspects, such as layers of systemic contradictions, conflicts, and constraints.

The second stage entails drawing a rich picture, whereby the analyst collects, categorizes, and synthesizes relevant information to produce a comprehensive depiction of the problematic context. The third step focuses on formulating root definitions, which determine the specific perspectives from which the issue should be understood. During this phase, subsystems related to the problem are identified and named—an essential process for modeling, as these names guide the development of system representations. The formulation of root definitions enables analysts to define each organizational activity clearly and provides a coherent foundation for system modeling. It is a transitional process whereby existing processes, activities, and conditions are treated as inputs, refined through SSM, and subsequently transformed into structured outputs. Based on the derived root definitions, conceptual models are developed in the fourth stage to represent the system's ideal functioning. Conceptual model design refers to the development of a representation that explains the conditions of the problem situation. Typically, a separate conceptual model is created for each root definition, and following coordination, a consensus model is developed jointly by analysts and stakeholders. A conceptual model serves as a schematic of activities that illustrate what the systems—defined by the respective root definitions—are intended to do. At this stage, the goal is to construct a purpose-driven system model that identifies the necessary activities for achieving desirable outputs for system beneficiaries. The outputs of these two steps—combined with tools such as rich pictures, CATWOE analysis, and PQR analysis—enable the identification of systems, subsystems, and their corresponding inputs and outputs.

This method facilitates the incorporation of diverse perspectives and operational experiences from power plant stakeholders into the modeling process, guiding decision-making toward a holistic and participatory approach. Furthermore, the conceptual linkage between input, process, output, and efficiency evaluation in SSM aligns with the analytical framework of DEA, enabling synergy between the two methodologies (Checkland & Scholes, 1999; Mingers et al., 2009; Susanty et al., 2022). The final three stages of SSM—comparing the conceptual model to real-world conditions, defining improvement-oriented changes, and planning for change implementation—have limited relevance to the identification of inputs and outputs, which is the primary objective of this study within the DEA framework. These later steps may prove useful in enhancing system performance only after the mathematical DEA algorithms have been implemented.

Figure 1.
Process of Soft Systems Methodology (SSM)



Results

In this study, data analysis was conducted using a hybrid approach integrating Soft Systems Methodology (SSM) and Data Envelopment Analysis (DEA). The objective of this integration was to simultaneously leverage the advantages of systems thinking to gain a deeper understanding of the problem and to facilitate precise efficiency evaluation of selected gas-fired power plants in southern Iraq.

Soft Systems Methodology at the Macro-System Level

Step 1: Identifying and Addressing the Problematic Situation

The initial step in the SSM framework involves accurately identifying the problematic situation and developing a thorough understanding of the complex contextual conditions in which the issue occurs. In the present study—focused on assessing the efficiency of gas-fired power plants in southern Iraq—this step was carried out through semi-structured interviews with electricity sector experts, operational managers, power plant staff, and senior analysts from the Ministry of Electricity. Findings from this stage revealed that Iraq faces broad challenges across electricity supply, generation, and distribution, only some of which are attributable to technical or managerial deficiencies. Issues such as heavy reliance on imported electricity, inefficiencies in the financial structure of power plants, equipment obsolescence, misalignment between governmental policies and infrastructure needs, and the absence of a culture of efficient energy use collectively form a complex and deeply intertwined situation that renders electricity production in southern Iraq a multifaceted and systemic problem.

From a techno-economic perspective, challenges such as limited financial resources for power plant development, insufficient budgets for maintenance and equipment renewal, delays in budget approval and allocation, and weak cost recovery mechanisms were identified. These issues have created production bottlenecks and reduced operational efficiency. On the environmental front, the use of heavy fuels, fuel leakage, and insufficient cooling water have contributed to extensive pollution and environmental degradation. Infrastructure-related challenges include the absence of advanced technologies, weak monitoring and smart control systems, and significant energy losses across transmission lines. In addition, the socio-human dimension of the problem encompasses uncontrolled population growth, informal electricity consumption in unauthorized settlements, employee distrust toward regulatory bodies, and the lack of specialized training and effective public awareness regarding energy consumption. Therefore, this initial step—grounded in qualitative data collection, stakeholder perception analysis, and multidimensional problem assessment—has established a robust foundation for the subsequent stages of SSM. Understanding this complex situation enables conceptual modeling, root definition formulation, and, ultimately, quantitative performance analysis via DEA. The defining characteristic of this phase is the acceptance of diverse viewpoints and the pursuit of understanding the 'subjective realities' of all stakeholders involved, recognizing that effective solutions to complex problems can only be designed through mutual understanding and multidimensional representation.

Step 2: Illustration of the Problematic Situation through Rich Pictures

In this stage, the findings from previous step are visually represented using a "rich picture" format. The purpose of constructing this visual illustration is to facilitate the conceptualization of the complex relationships among stakeholders, processes, resources, constraints, and conflicts inherent in the problematic situation. Rather than serving as a technical or mathematically precise diagram, the rich picture reflects the analyst's subjective and systemic understanding of the issue—seeking to express complexity in a simplified and comprehensible visual language. Figure 2 depicts the rich picture of gas-fired electricity generation plants.

Figure 2.

Rich picture of gas-fired electricity generation plants

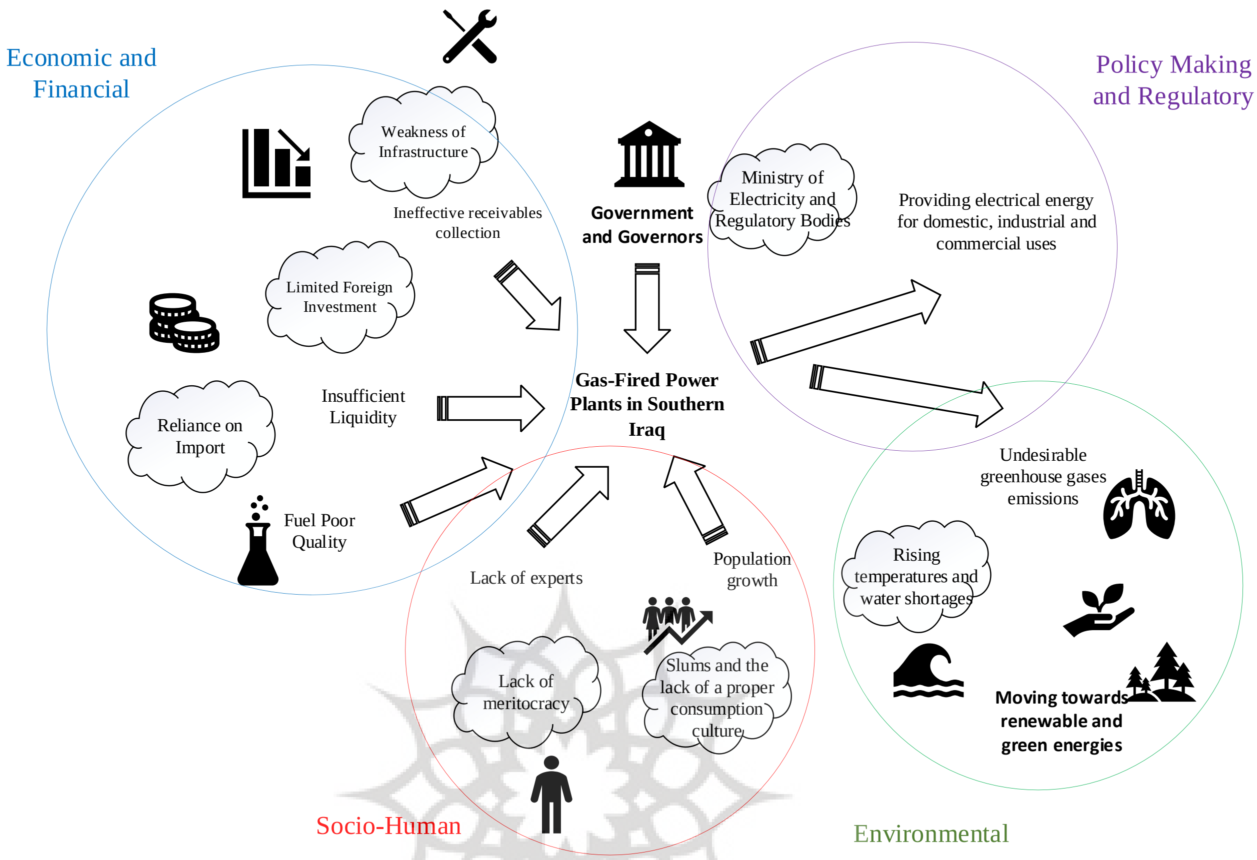


Figure 2 presents a conceptual model of the multidimensional challenges facing gas-fired power plants in Iraq, categorized into four primary domains: economic-financial, socio-human, policy and regulatory, and environmental. Within the economic dimension, factors such as aging infrastructure, limited foreign investment, dependence on electricity imports, and inadequate financial allocation have undermined the productivity of these plants. In the human dimension, shortages of skilled personnel, weak meritocracy, and inefficient energy consumption habits exert additional pressure on the grid. From a policy perspective, deficient governmental oversight, land acquisition issues, and unequal electricity distribution constitute major obstacles. Environmentally, greenhouse gas emissions, rising temperatures, and pollution underscore the urgency of transitioning to cleaner energy sources. This visual model highlights the necessity of adopting a systemic and integrated approach to improve the performance of Iraq's gas-fired electricity generation infrastructure.

Step 3: Development of Root Definition

To formulate the root definition—a core component of Soft Systems Methodology (SSM)—the CATWOE technique was employed. Root definitions may vary depending on differing worldviews; however, they must align with the decision-maker's perspective regarding the problem. In this study, CATWOE components were identified for gas-fired electricity generation plants as a unified system, leading to the articulation of a root definition. Table 2 presents the CATWOE elements for gas-fired power plants in Iraq.

Table 2.
CATWOE Elements for Gas-Fired Power Plants in Iraq

CATWOE Component	Variable Description
Customers (C)	Electricity transmission companies; Iraqi citizens (household consumers), factories (industrial users), and all commercial establishments (commercial users)
Actors (A)	Gas-fired power plants generating electricity for various industrial and commercial sectors; Ministry of Electricity; General Electric Production Company and subsidiaries
Transformation (T)	Supplying electric energy to citizens and critical national infrastructure, ensuring continuous and reliable productivity
Worldview (W)	Delivering energy at minimal cost, distributed equitably across social classes, and minimizing environmental impacts
Owners (O)	Central and local governments involved in power generation development; Ministry of Electricity
Environmental Constraints (E)	Economic constraints (e.g., investment gaps, financial allocation shortages, liquidity issues); legal limitations (e.g., land acquisition); environmental constraints (e.g., excessive gas emissions, high temperatures, water scarcity); technical and infrastructural barriers (e.g., outdated and low-quality equipment, lack of expertise in design and development)

The development of the root definition was informed by a series of interviews conducted with managers and technical specialists from gas-fired power generation companies in southern Iraq, as well as through structured CATWOE analysis. The outcomes of this process were shared with the interviewees across multiple iterative rounds, and, following validation and refinement, the finalized root definition was established as follows:

"The purpose of Iraq's gas-fired electricity generation companies is to utilize the country's natural resources to produce electricity for Iraqi citizens (household consumption), industrial facilities (industrial consumption), and commercial establishments (commercial consumption) at the lowest possible cost and with equitable access across all social classes, while minimizing adverse environmental impacts. In pursuit of this mission, strategic policies for power plants are formulated by the central government—through the Ministry of Electricity—and local authorities. The presence of economic constraints (e.g., limited investment, inadequate financial allocations, liquidity shortages), legal barriers (e.g., land acquisition for expansion), environmental challenges (e.g., excessive emissions, elevated temperatures, water scarcity), and technical-infrastructural limitations (e.g., outdated and poor-quality equipment, lack of technical expertise in design and development) have compelled Iraq to rely on electricity imports from neighboring countries to meet the needs of key stakeholders. The primary objective of this system is to evaluate the efficiency of gas-fired power plants, conduct periodic monitoring and continuous improvement, and identify strengths and weaknesses in order to achieve established goals—namely, minimal environmental pollution, maximum production efficiency, and optimal customer satisfaction."

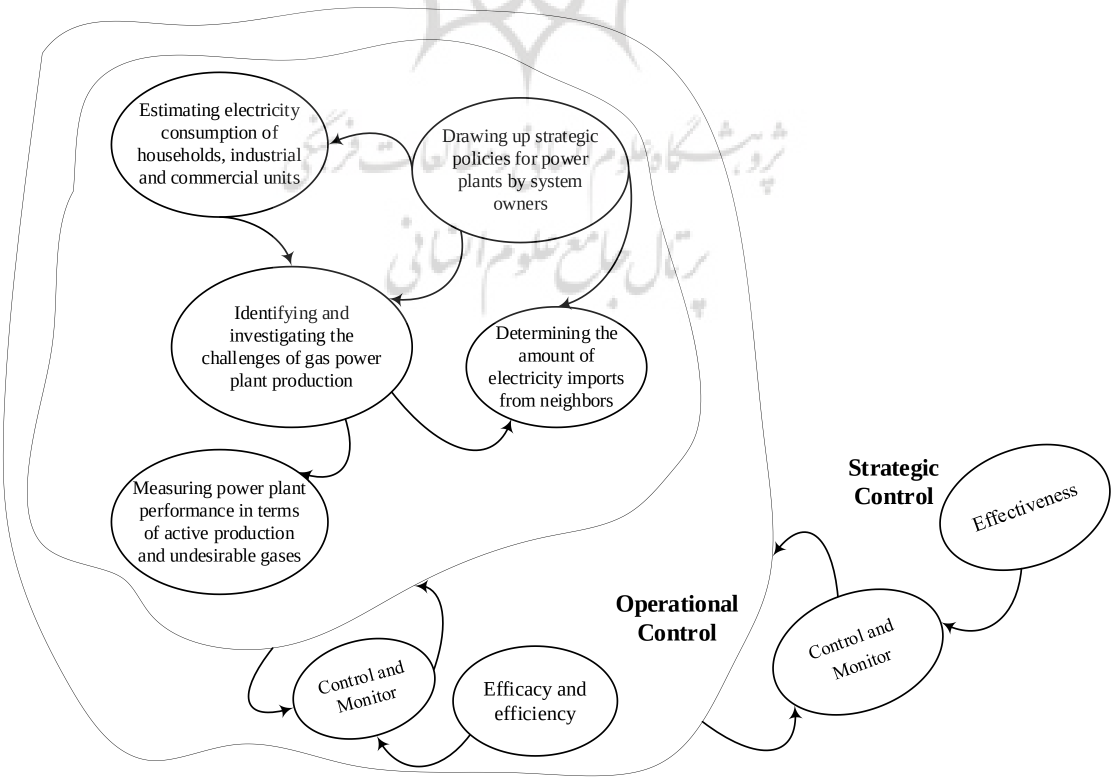
Step 4: Conceptual Model Development

In this stage of the Soft Systems Methodology (SSM) approach, the conceptual model of gas-fired electricity generation plants in Iraq is developed based on the previously formulated root definition and the 3E framework—comprising effectiveness, efficiency, and efficacy. Accordingly, an initial Level 1 conceptual model is constructed for the overall gas-fired electricity production system in Iraq, aimed at transforming inputs into desired outputs, such as electricity generation with minimal environmental impact and maximum customer satisfaction.

This model distinguishes between input resources and output outcomes while accounting for uncontrolled environmental variables such as ambient temperature. It further evaluates the functional dimensions of the system through the lens of the 3E framework. In this context, a PQR analysis was conducted to define performance criteria for each of the three core dimensions: (1) *Efficacy*—focused on the actual electricity output and pollutant levels; (2) *Efficiency*—concerned with the ratio of outputs to resource consumption such as fuel and electricity usage; and (3) *Effectiveness*—centered on the extent to which outputs align with higher-order objectives, including customer satisfaction and environmental protection. Figure 3 illustrates the conceptual model of Iraq's gas-fired electricity generation system, developed in accordance with the root definition.

Figure 3.

Conceptual Model of Gas-fired Electricity Generation Plants based on Root Definition



Given the complexity and multidimensional nature of the issue, the overarching conceptual model has been disaggregated into seven distinct subsystems. Each subsystem was developed at a lower level through expert interviews and qualitative content analysis, and possesses its own root definition based on Soft Systems Methodology (SSM):

- ***Economic Subsystem:*** Focuses on attracting foreign investment and managing liquidity within power plants to facilitate contractor payments, promote project development, and enhance workforce motivation.
- ***Environmental Subsystem:*** Aims to reduce pollution through a transition to renewable energies such as wind power, minimize industrial waste, and conserve water resources amid the critical conditions of the Tigris and Euphrates rivers.
- ***Supply Subsystem:*** Concentrates on improving fuel quality via filtration technologies and managing gas storage to regulate imports and address supply volatility across seasonal variations.
- ***Human Resources Subsystem:*** Targets the improvement of human resource management systems, provision of specialized staff training, and reduction of contractor dependency through technical skill development and morale strengthening.
- ***Technology and Infrastructure Subsystem:*** Envisions modernizing outdated networks, upgrading equipment, and deploying clean energy technologies, subject to adequate financial support.
- ***Social Subsystem:*** Seeks to promote public awareness and cultural transformation regarding responsible electricity consumption and prevention of misuse, emphasizing consumer-level behavioral interventions.
- ***Managerial Subsystem:*** Prioritizes organizational and administrative restructuring, capability-based planning, meritocratic governance, and the avoidance of non-specialist interference in strategic affairs.

Each of these subsystems interacts to form the broader system of gas-fired power plants in Iraq. In accordance with the SSM approach, they require continuous monitoring and performance evaluation using the 3E framework—effectiveness, efficiency, and efficacy (PQR). This multi-layered model not only enables more precise analysis through quantitative techniques such as Data Envelopment Analysis (DEA), but also provides a robust foundation for policy decision-making and structural reform within Iraq's electricity sector.

Soft Systems Methodology at the Subsystem Level

Given the specific focus on gas-fired power plants, the subsystems are defined through the identification and analysis of challenges related to power generation within these facilities. Accordingly, a separate root definition has been formulated for each subsystem, as presented in Table 3.

Table 3.

Root Definitions of Subsystems

Subsystems	Root Definition
Economic	Enhancing liquidity in power plants through foreign investment and monitoring receivables, aimed at facilitating contractor payments, advancing project development, and improving the reward system to motivate personnel.
Environmental	Transitioning toward renewable energy sources such as wind to mitigate pollution beyond environmental standards, reduce industrial waste and emissions, and decrease water consumption in light of the critical condition of the Tigris and Euphrates rivers.
Supply	Utilizing purifiers and separators to improve fuel quality—given the prevalence of low-grade gas and impurities—and deploying storage tanks to balance gas consumption and manage import schedules throughout the year.
Human Resources	Advancing human resource management systems and specialized personnel training for handling complex and modern equipment, with the goal of reducing reliance on contract workers and fostering employee resilience and commitment.
Technology & Infrastructure	Securing necessary financial resources to strengthen operational systems, storage capacities, maintenance and repair protocols, modernize outdated networks, and adopt advanced renewable energy technologies.
Social	Promoting public awareness and cultural transformation to ensure responsible electricity usage and prevent misuse in power generation and distribution systems, in consideration of Iraq's changing demographic landscape.
Managerial	Improving managerial efficiency and effectiveness through administrative and organizational reform, with a focus on competency-based planning, meritocratic principles, and limiting non-specialist interference in management processes.

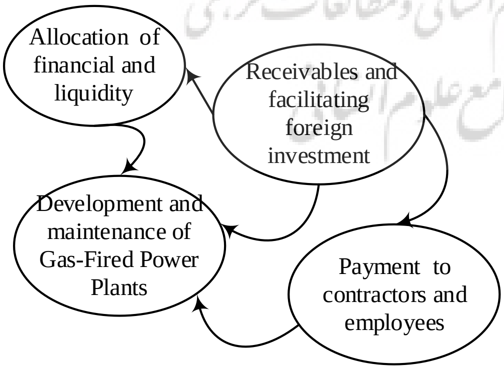
Conceptual and system models at the seven subsystem levels including economic, environmental, supply, human resource, technology & infrastructure, social, and managerial aspects depicted in Figure (4).

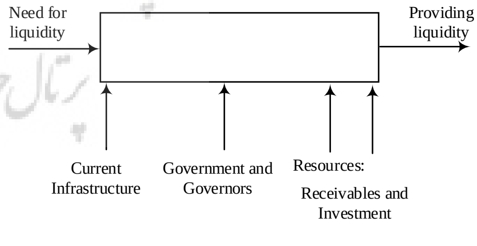
Figure 4.

Conceptual and System Models at the Subsystem Level

Subsystems | **Conceptual Model** | **System Model**

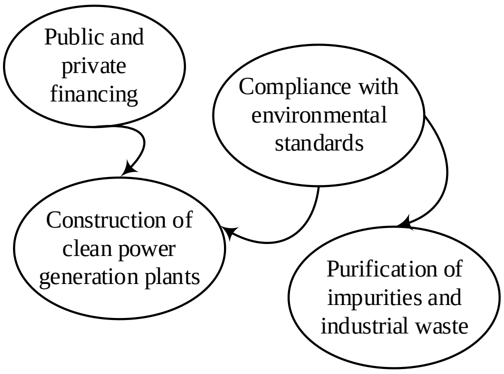
Economic

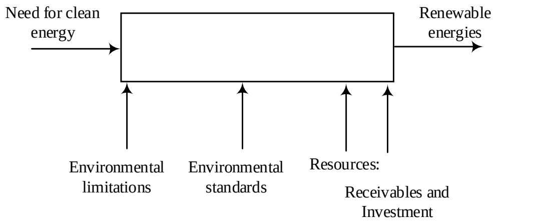




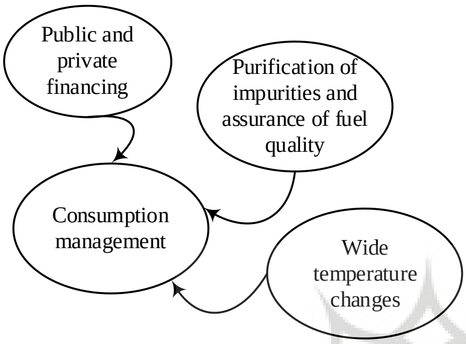
Subsystems	**Conceptual Model**	**System Model**

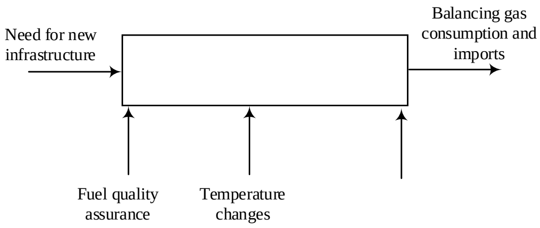
Environmenta l



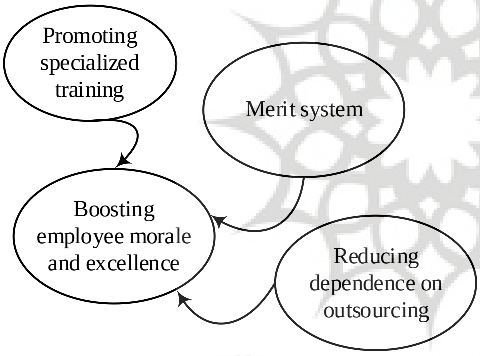


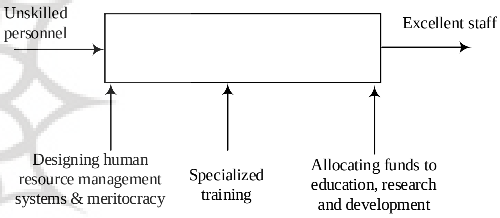
Supply



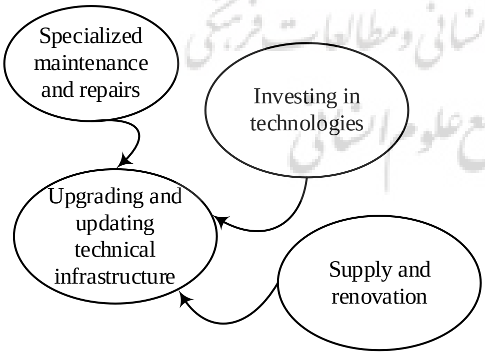


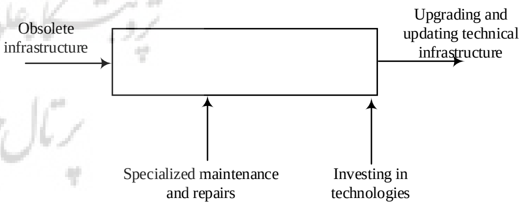
Human Resources





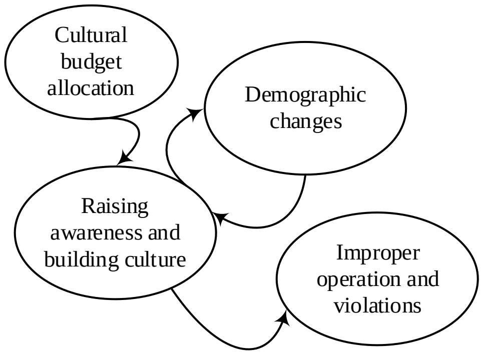
Technology & Infrastructure

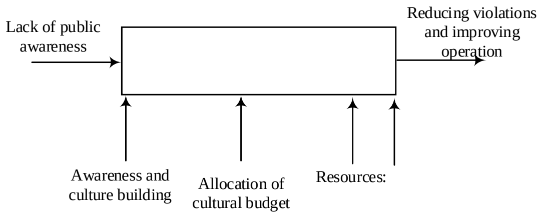




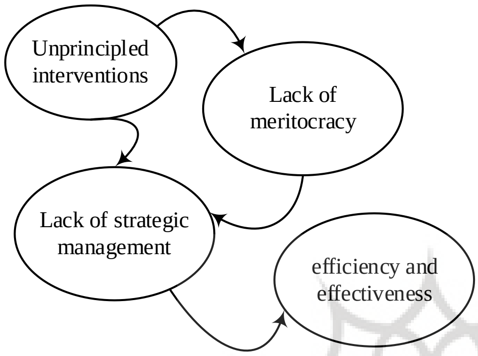
Subsystems — **Conceptual Model** — **System Model**

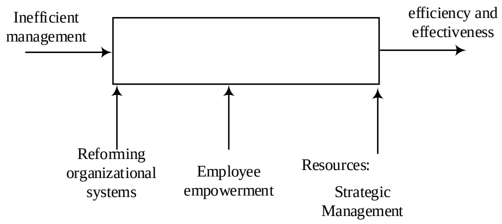
Social





Managerial





DEA's Inputs and Outputs

In the evaluation of decision-making units, including gas-fired power plants, Data Envelopment Analysis (DEA) is recognized as one of the widely applied non-parametric methods. However, in many real-world studies, decision-makers face multiple objectives and priorities that are not necessarily achievable simultaneously. Under such circumstances, reliance solely on classical DEA may yield optimal—but unrealistic—results. Accordingly, in this study, Soft Systems Methodology (SSM) is employed to improve analytical precision and better align the DEA model with the actual multi-criteria conditions of the power plants, particularly in identifying relevant input and output variables.

In the technology and infrastructure dimension, factors such as reliance on obsolete equipment, lack of modern operational and monitoring systems, and scarcity of renewable technologies have contributed to decreased annual output, increased internal energy consumption, and heightened greenhouse gas emissions. Environmentally, challenges such as pollutant emissions, unsanitary waste disposal, and water shortages have had a direct impact on plant performance. Economically, deficiencies in investment, liquidity constraints, and inadequate financial resource allocation have undermined productivity. From a managerial and human resources standpoint, the absence of skilled personnel, insufficient training, and structural issues within the decision-making framework have led to serious inefficiencies. Socially, factors such as unplanned population growth, expansion of informal settlements lacking consumption infrastructure, and poor electricity-use culture have significantly affected the performance of the country's gas-fired power system. The development of the conceptual and systemic model at the second level (i.e., the seven subsystems) resulted in the identification of key dimensions and indicators which are presented in Table 4.

Table 4.

Dimensions and Associated Indicators

Dimension	Indicators
Economic	Insufficient financial allocation and liquidity management Ineffective receivables collection Limited foreign investment
Environmental	Necessity to adopt renewable energy sources such as wind power Pollution exceeding standard thresholds Water resource scarcity
Supply	Inadequate and poor-quality gas fuel Lack of access to critical materials and spare parts
Human Resources	Absence of trained personnel Overreliance on contract-based labor Insufficient expertise in equipment design and development
Managerial	Absence of actionable planning aligned with existing capabilities Bureaucratic inefficiencies and non-specialist interference Poor appointment practices and disregard for meritocracy
Technology & Infrastructure	Deficiency in modern operational, maintenance, and monitoring systems Reliance on outdated technologies and deteriorated infrastructure Lack of renewable energy technologies such as wind power systems
Social	Expansion of informal settlements without metering systems Irregular population growth Low public awareness and culture regarding electricity usage

Based on these analyses, the final input and output variables were selected according to their relevance, measurability, and data availability. The findings presented in Table (4) demonstrate that the identified indicators can be redefined according to their measurable effects on both tangible inputs and quantifiable outputs. Notably, several indicators influence inputs and outputs concurrently. For instance, within the economic dimension, three key factors—insufficient financial allocation and liquidity management, ineffective receivables collection, and limited foreign investment—have substantially contributed to reduced electricity production in Iraq. These indicators simultaneously affect two critical variables: annual electricity production (output) and natural gas consumption (input) in gas-fired power plants.

Within the environmental dimension, several critical issues have significantly influenced both undesirable gas emissions and annual production outputs. The Necessity to adopt renewable energy sources such as wind power, pollution exceeding standard thresholds, and water resource scarcity, have collectively contributed to these operational challenges. Furthermore, the inadequate and poor-quality gas fuel, and Lack of access to critical materials and spare parts has adversely affected electricity generation capacity while simultaneously elevating natural gas consumption and associated emissions.

From an organizational management perspective, systemic human resource deficiencies have emerged as substantial barriers to optimal plant performance. The absence of trained personnel, overreliance on contract-based labor, and insufficient expertise in equipment design and development have significantly compromised operational efficiency. These workforce challenges are compounded by strategic management shortcomings, including absence of actionable planning aligned with existing capabilities, bureaucratic inefficiencies and non-specialist interference, poor appointment practices and disregard for meritocracy principles. These interrelated factors, rooted in insufficient workforce development, training programs, and research and development investments, collectively impair electricity production capacity. Addressing these multidimensional challenges requires comprehensive reforms in both human resource management practices and broader organizational management strategies.

Within the technological and infrastructure dimension, deficiencies in modern operational, maintenance, and monitoring systems, coupled with continued reliance on outdated technologies and deteriorated infrastructure, have contributed to reduced annual electricity generation while simultaneously increasing both plant energy consumption (electricity depreciation) and emissions of environmentally harmful gases including carbon dioxide and methane. Furthermore, lack of renewable energy technologies such as wind power systems, has necessitated excessive consumption of natural gases, thereby exacerbating undesirable emissions. This technological gap has perpetuated Iraq's dependence on imported gas from neighboring nations to meet its energy demands.

From a social perspective, several factors have placed additional strain on electricity generation capacity. The expansion of informal settlements without metering systems, irregular population growth, and low public awareness and culture regarding electricity usage have collectively increased pressure on gas-fired power plants. These social challenges have further compounded the technical and infrastructural limitations, creating a multifaceted crisis in Iraq's energy sector.

Table (5) depicts dimensions, indicators, and scalable/quantifiable inputs and outputs for DEA model.

Table 5.

Scalable/quantifiable inputs and outputs for DEA

Dimension	Indicators	Inputs	Outputs
	Insufficient financial allocation and liquidity management	-	Annual electricity production
Economic	Ineffective receivables collection	-	Annual electricity production
	Limited foreign investment	Natural gas consumption	Annual electricity production
Environmental	Necessity to adopt renewable energy sources such as wind power	Natural gas consumption	Annual electricity production

Dimension	**Indicators**	**Inputs**	**Outputs**
Supply	Pollution exceeding standard thresholds	-	Unfavourable gases (CO2, CH4, N2O)
	Water resource scarcity	-	Annual electricity production
	Inadequate and poor-quality gas fuel	Natural gas consumption	Annual electricity production Unfavourable gases (CO2, CH4, N2O)
	Lack of access to critical materials and spare parts	-	Annual electricity production
Human Resources	Absence of trained personnel	Number of employees training programs, and research and development	Annual electricity production
	Overreliance on contract-based labor	Number of employees training programs, and research and development	-
	Insufficient expertise in equipment design and development	Number of employees training programs, and research and development	Annual electricity production Depreciation of electricity consumption
Managerial	Absence of actionable planning aligned with existing capabilities	Number of employees training programs, and research and development	Annual electricity production
	Bureaucratic inefficiencies and non-specialist interference	Number of employees	-
	Poor appointment practices and disregard for meritocracy	Number of employees	-
Technology & Infrastructure	Deficiency in modern operational, maintenance, and monitoring systems	-	Annual electricity production Unfavourable gases (CO2, CH4, N2O) Depreciation of electricity consumption
	Reliance on outdated technologies and deteriorated infrastructure	-	Annual electricity production Unfavourable gases (CO2, CH4, N2O)

Dimension	Indicators	Inputs	Outputs
			Depreciation of electricity consumption
	Lack of renewable energy technologies such as wind power systems	Natural gas consumption	Unfavourable gases (CO_2, CH_4, N_2O)
	Expansion of informal settlements without metering systems	-	Annual electricity production
Social	Irregular population growth	-	Annual electricity production
	Low public awareness and culture regarding electricity usage	-	Annual electricity production

Discussion and Conclusion

The present study aims to develop an integrated framework for identifying input and output variables and applying Data Envelopment Analysis (DEA) to evaluate the efficiency of gas-fired power generation plants in southern Iraq. To this end, Soft Systems Methodology (SSM) was utilized to analyze the complex institutional, social, and managerial dimensions of the issue. The primary objective was to identify the root causes of inefficiency and propose system-based solutions to enhance power plant performance.

Upon initial examination, Soft Systems Methodology (SSM) and Data Envelopment Analysis (DEA) may appear fundamentally dissimilar, given that SSM is a conceptual approach grounded in subjective epistemology, whereas DEA constitutes a mathematical programming technique designed to assess the relative efficiency of decision-making units (DMUs) through input-output data analysis, reflecting a positivist paradigm (Mingers, 2003). Nevertheless, notable parallels exist between the two methodologies. Specifically, SSM can be effectively integrated with DEA for three compelling reasons, playing a critical role in defining the input and output indicators for DMUs. First, SSM offers a systematic and structured framework for analyzing an organization's key activities, which is essential for evaluating organizational efficiency and performance. In this context, the application of Root Definitions (RD) and Conceptual Models (CM) enhances problem structuring within the DEA methodology. Second, SSM incorporates diverse perspectives and worldviews in defining input and output variables. The methodology constructs models based on specific *Weltanschauungen* (worldviews) (Mingers, 2003), which may differ among stakeholders. These models represent notional or conceptual systems in which defined activities convert inputs into outputs delivered to a beneficiary. By systematically mapping stakeholders, their respective challenges, and the interactions between them, SSM facilitates a comprehensive identification of relevant inputs and outputs (Soltan Mohammadi et al. 2012). Finally, the definition of *transformation* in DEA varies depending on stakeholder perspectives. By employing SSM, consensus among key organizational stakeholders can be achieved when evaluating performance. Crucially, the conversion of inputs into outputs constitutes the foundational mechanism of this integrated approach. This methodology significantly mitigates the influence of subjective decision-maker bias in selecting input and output variables for efficiency measurement. Grounded in systems thinking, SSM systematically identifies inputs and outputs by (1) mapping relevant stakeholders and their associated challenges, and (2) analyzing the interactions and relationships among them.

The findings reveal a significant discrepancy between input resources and actual output levels across most facilities. Moreover, results indicate that imbalanced utilization of human resources, inadequate specialized training, and heavy reliance on external contractors constitute key contributors to inefficiency within the human capital domain. These insights align with recent studies such as Wang et al. (2024) in Southeast Asian countries, where it is emphasized that human resource productivity is no less influential than technical factors in determining energy efficiency.

From a technical standpoint, several challenges were identified, including the failure to modernize equipment, the absence of performance control and monitoring systems, and the lack of advanced operational infrastructure. These findings align with the studies conducted by Li and Tao (2017) and Rahman et al. (2023), which underscore that purely technical analyses—when undertaken without consideration of operational frameworks and broader policy environments—do not yield effective solutions. In addition, the environmental dimension of power plant performance was examined, revealing that pollutant emissions in most units exceed global standards. Given the climatic conditions in southern Iraq, the lack of water recycling systems and weaknesses in gas storage and purification processes have exacerbated environmental challenges. These findings correspond with reports by the International Energy Agency (2024), which warn that fossil fuel-dependent countries must accelerate their transition toward clean energy sources to prevent compounding environmental and economic crises.

At the decision-making and institutional structure level, findings indicate the absence of integrated planning, excessive centralization in policymaking, and managerial instability. For example, most power plants lack the authority to attract investment or enter into long-term contracts for fuel and spare parts procurement, resulting in operational uncertainty. In addition, data reveal that poor consumption habits and the lack of public education on energy optimization have contributed to high levels of energy waste on the demand side. Comparative studies, such as the work by Fu et al. (2023) examining the electricity systems of Pakistan and Malaysia, have also highlighted that participatory policymaking and consumer-focused education exert a direct impact on reducing grid pressure and enhancing overall system productivity.

Based on the aforementioned findings, several practical recommendations can be proposed. First, the Iraq Government should prioritize targeted foreign investment for the modernization of power plant technologies and actively pursue public–private partnership models. Second, reforming the human resource structure—through redesigning recruitment, training, and promotion processes and gradually eliminating dependence on non-specialized contractors—is imperative. Third, the development of realtime intelligent monitoring systems for fuel quality control, consumption management, and performance assessment at individual power plants could lead to continuous system optimization. Fourth, establishing provincial-level decision-making units with clearly defined financial and technical authority for power plants may help mitigate excessive centralization and reduce policy-making delays. Fifth, public education and awareness campaigns—implemented in collaboration with media outlets—should become a key component of the national energy strategy in order to sustainably manage electricity demand. Finally, a gradual transition to renewable energy sources in southern Iraq, particularly solar energy given the region's high climatic potential, must be addressed at the policy level.

The innovative contribution of the present study lies in its adoption of an integrated DEA–SSM approach, which, unlike existing regional literature, enables a multidimensional and in-depth analysis of power plant efficiency. In contrast to conventional studies that rely solely on technical assessments, this research simultaneously incorporates managerial, human, institutional, environmental, and technological factors—demonstrating that power plant efficiency is not exclusively a technical construct, but rather the outcome of interactive dynamics across various structural and functional layers.

Nevertheless, the study faced certain limitations. Chief among these was the restriction of the sample to power plants in southern Iraq and the lack of access to complete datasets for some facilities due to administrative and security constraints. Future researchers are encouraged to expand the geographical scope to include the entire country and to adopt dynamic modeling approaches that account for policy scenarios related to climate change and regional migration patterns. Additionally, exploring optimal energy portfolios—particularly solar and wind energy in southern Iraq—could offer a more strategic outlook for the nation's power sector.

References

Abed, F. T., ALRikabi, H. T. S., & Ibrahim, I. A. (2020). Efficient Energy of Smart Grid Education Models for Modern Electric Power System Engineering in Iraq. In IOP Conference Series: Materials Science and Engineering (Vol. 870, No. 1, p. 012049). IOP Publishing . https://doi.org/10.1088/1757-899X/870/1/012049.

Adom, P. K. (2024). The socioeconomic impact of climate change in developing countries in the next decades. Center for Global Development, Heliyon, 10(15), e35134. https://doi.org/10.1016/j.heliyon.2024.e35134.

Altai, H. D. S., Abed, F. T., Lazim, M. H., & ALRikabi, H. T. S. (2022). Analysis of the problems of electricity in Iraq and recommendations of methods of overcoming them. Periodicals of Engineering and Natural Sciences, 10(1), 607-614. https://doi.org/10.21533/pen. v10i1.2722.

Arabshahi Delouee M, Falahi M A, Salehnia N. (2020) Energy Efficiency of Energy-Intensive Industries in Iran: Application of Data Envelopment Analysis and Gamma Test. Quarterly Journal of Energy Policy and Planning Research, 6 (3) :45-84. http://epprjournal.ir/article-1-827-en.html. [In Persian]

Bampatsou, C., Papadopoulos, S., & Zervas, E. (2013). Technical efficiency of economic systems of EU-15 countries based on energy consumption. Energy Policy, 55, 426-434. https://doi.org/10.1016/j.enpol.2012.12.021

Belaid, F., Sanin, M. E., & Lazaric, N. (2023). Energy efficiency and residential energy consumption: current challenges, policies, and emerging trends. Frontiers in Energy Research, 11, 1218527. https://doi: 10.3389/fenrg.2023.1218527.

Checkland, P., & Scholes, J. (1999). Soft systems methodology in action. John Wiley & Sons. ISBN: 978-0-471-98605-8.

Chen, J., Shen, Z., Kang, Q., Qian, X., Li, S., Jiang, P., & Huang, X. (2022). Chemical adsorption on 2D dielectric nanosheets for matrix free nanocomposites with ultrahigh electrical energy storage. Science Bulletin, 67(6), 609-618. https://doi: 10.1016/j.scib.2021.10.011.

Dong, K., Jiang, Q., Liu, Y., Shen, Z., & Vardanyan, M. (2024). Is energy aid allocated fairly? A global energy vulnerability perspective. World Development, 173, 106409. https://doi.org/10.1016/j.worlddev.2023.106409.

Ember. (2024). Iraq: Electricity profile. Retrieved from https://ember-climate.org.

Energy Information Administration (EIA). (2023). Electricity explained. Retrieved from https://eia.gov.

Ervural, B. C., Zaim, S., & Delen, D. (2018). A two-stage analytical approach to assess sustainable energy efficiency. Energy, 164, 822-836. https://doi.org/10.1016/j.energy.2018.08.213.

Esfandiari, M., & Saati, S. (2024). Two-stage DEA model with complex numbers: a case study of power plants in Iran. OPSEARCH, 1-22. https://doi.org/10.1016/j.energy.2018.08.213

Fu, Z., Zhou, Y., Li, W., & Zhong, K. (2023). Impact of digital finance on energy efficiency: Empirical findings from China. Environmental Science and Pollution Research, 30(2), 2813-2835. https://doi.org /10.1007/s11356-022-22320-5

Guang, F., Wen, L., & Sharp, B. (2022). Energy efficiency improvements and industry transition: An analysis of China's electricity consumption. Energy, 244, 122625. https://doi.org/10.1016/j.energy.2021.122625.

Hassan, Q., Viktor, P., Al-Musawi, T. J., Ali, B. M., Algburi, S., Alzoubi, H. M., ... & Jaszczur, M. (2024). The renewable energy role in the global energy Transformations. Renewable Energy Focus, 48, 100545. https://doi.org/10.1016/j.ref.2024.100545

International Energy Agency (IEA). (2024). World Energy Outlook. Retrieved from https://iea.org.

Karami, M., Rastegar, A.A., Azar, A., Feiz, D., Esfidani, M.R. (2020). Identifying the factors affecting the selection of B2B online market entry strategies using soft system methodology, Journal of System Management, 6(2): 55-80. https://doi.org/10.30495/jsm.2020.677236.

Khosravi, M. R., Shahroodi, K., Amirteimoori, A. and Delafrooz, N. (2022). Developing an Analytical-Mathematical Model for Evaluating the Efficiency of the Power Production, Transmission, and Distribution Companies in the Electric Power Industry of Iran: A Network Data Envelopment Analysis (NDEA) Approach with Undesirable Outputs. *Industrial Management Journal*, *14*(2), 220-249. https://doi: 10.22059/imj.2022.339078.1007925. [In Persian]

Li, MJ., and Tao, WQ. (2017). Review of Methodologies and Polices for Evaluation of Energy Efficiency in High Energy-consuming Industry. Applied Energy, 187, 203–215. https://doi.org/10.1016/j.apenergy.2016.11.039.

Mahfoudh, S., & Amar, M. B. (2014). The importance of electricity consumption in economic growth: The example of African nations. The Journal of Energy and Development, 40(1/2), 99-110. http://www.jstor.org/stable/24813095.

Mahmood, N. S., Kamat, S. R., & Ajmi, A. A. (2017). Increase the performance of power station: Results and analysis of an empirical study of the ISO 50001 energy management systems in the Iraqi ministry of electricity. https://doi.org/14.9831/1444-8939.2016/4-2/MRR.10

Mamipour, S. and Najafzadeh, B. (2016). Environmental Efficiency Assessment of Iranian Electric Power Companies: Comparison between Radial and Non-Radial Models. *Quarterly Journal of Applied Theories of Economics*, *3*(3), 153-178. https://ecoj.tabrizu.ac.ir/article_5440.html?lang=en [In Persian]

Mills, R., & Salman, M. (2020). Powering Iraq: Challenges facing the electricity sector in Iraq. Al-Bayan Center for Planning and Studies: Baghdad, Iraq, 1-30. https://library.fes.de/pdf-files/bueros/amman/16923.

Mingers, J., Liu, W., & Meng, W. (2009). Using SSM to structure the identification of inputs and outputs in DEA. Journal of the Operational Research Society, 60(2), 168-179. https://doi.org/10.1057/palgrave.jors.2602542.

Mohd Chachuli, F. S., Ahmad Ludin, N., Mat, S., & Sopian, K. (2020). Renewable energy performance evaluation studies using the data envelopment analysis (DEA): A systematic review. Journal of Renewable and Sustainable Energy, 12. https://doi.org/10.1063/5.0024750.

Munisamy, S., & Arabi, B. (2015). Eco-efficiency changes in power plants: using a slacks-based measure for the meta-frontier Malmquist–Luenberger productivity index. Journal of cleaner production, 105, 218-232. https://doi.org/10.1016/j.jclepro.2014.12.081.

Nadhum, A. A., & Erzaij, K. R. (2020). Evaluating implementation of electric power generation projects in Iraq. In IOP Conference Series: Materials Science and Engineering, https://doi.org/10.1088/1757-899X/901/1/012034

Nijkamp, P., Kourtit, K., & Dentinho, T. P. (2025). Infrastructure reconstruction planning in post-conflict areas – a multidimensional resilience assessment for Iraq. *Planning Practice & Research*, *40*(4), 733–757. https://doi.org/10.1080/02697459.2024.2440258.

Patyal, V. S., Kumar, R., Lamba, K., & Maheshwari, S. (2023). Performance evaluation of Indian electricity distribution companies: An integrated DEA-IRP-TOPSIS approach. Energy Economics, 124, 106796. https://doi.org/10.1016/j.eneco.2023.106796.

Rahman, A. S. A., Ali, S. A. S., Isa, M. R., Ali, F., Kamaruddin, D., & Baharuddin, M. H. (2023). Performance Assessment of Malaysian Fossil Fuel Power Plants: A Data Envelopment Analysis (DEA) Approach. International Journal of Renewable Energy Development, 12(2), 247. https://doi.org/10.14710/ijred.2023.48487

Radsar, M. , Kazemi, A. , Mehrgan, M. and Razavi Hajiagha, S. H. (2021). Designing an algorithm based on network data envelopment analysis with desirable and undesirable indicators for the evaluation of the Iranian power industry. *Industrial Management Journal*, *13*(1), 1-26. https://doi:10.22059/imj.2021.298553.1007721. [In Persian]

Rodríguez-Lozano, G., & Cifuentes-Yate, M. (2021). Efficiency assessment of electricity generation from renewable and non-renewable energy sources using Data Envelopment Analysis. International Journal of Energy Research, 45(13), 19597-19610. https://doi.org/10.1002/er.6959.

Soltan Mohammadi, N., Abooyee Ardakan, M., Mehregan, M. (2012). Identify Key Factors in the Data Envelopment Analysis (DEA) for Evaluating University Departments by Using Soft System Methodology (SSM), Industrial Management Journal, 4(1): 129-146. https://doi.org/10.22059/imj.2012.72263 [In Persian]

Sufia, Singh, A., Mishra, S. (2025). Operational efficiency and service quality of Indian electricity distribution utilities: A three-stage DEA and Malmquist Index analysis, Utilities Policy, 96, 102001. https://doi.org/10.1016/j.jup.2025.102001

Susanty, A., Purwanggono, B., & Al Faruq, C. (2022). Electricity distribution efficiency analysis using data envelopment analysis (DEA) and soft system methodology. Procedia

Computer Science, 203, 342-349. https://doi.org/10.1016/j.procs.2022.07.043

Valafar, M.A., Hamidi, N., Alborzi, M., Iranban, S.J. (2020). Systematic Structuring of the Business Domain of Local Mobile Apps Stores Using Soft Systems Methodology, Journal of System Management, 6(2) : 135-154. https://doi.org/10.30495/jsm.2020.677239

Wang, X., Lu, Y., Chen, C., Yi, X., & Cui, H. (2024). Total-factor energy efficiency of ten major global energy-consuming countries. Journal of Environmental Sciences, 137, 41-52. https://doi.org/10.1016/j.jes.2023.02.031

Wei, X., Zhao, R. (2024). Evaluation and spatial convergence of carbon emission reduction efficiency in China's power industry: Based on a three-stage DEA model with game cross-efficiency, Science of The Total Environment, 906, 167851. https://doi.org/10.1016/j.scitotenv.2023.167851

World Bank. (2023). Iraq Energy Sector Diagnostics. Retrieved from https://worldbank.org.

Worldometers. (2024). Iraq Electricity. Available at: https://www.worldometers.info/electricity/iraq-electricity ./

Xiao, Q. W., Tian, Z., & Ren, F. R. (2022). Efficiency assessment of electricity generation in China using meta-frontier data envelopment analysis: Cross-regional comparison based on different electricity generation energy sources. Energy Strategy Reviews, 39, 100767. https://doi.org/10.1016/j.esr.2021.100767

Xu, T., You, J., Li, H., & Shao, L. (2020). Energy efficiency evaluation based on data envelopment analysis: A literature review. Energies, 13(14), 3548. https://doi.org/10.3390/en13143548

Yadava, A. K., Chakraborty, S., Gupta, S. (2025). Benchmarking the performance of Indian electricity distribution companies: The applications of multi-stage robust DEA and SFA models, Energy Economics, 145, 108396. https://doi.org/10.1016/j.eneco.2025.108396

Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global indicators of sustainable development: Evaluation of the influence of the human development index on consumption and quality of energy. Energies, 13(11), 2768. https://doi.org/10.3390/en13112768

Zhang, Q., Zhang, R. (2025). An extended mixed-network DEA method to analyze the power supply system with shared resources, Energy, 324, 136110. https://doi.org/10.1016/j.energy.2025.136110.