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Smart Management for the Energy Sector in Egypt Using Geospatial Technology

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ABSTRACT

The energy problem in Egypt is one of the biggest strategic challenges faced by decision-makers. It is considered an obstacle affecting environmental sustainability and the sustainability of the energy sector in Egypt. The issue, especially in the electricity networks, lies in management the lack of inclusion of smart management mechanisms in the sector's administration, and the absence of the geographical dimension in linking network assets with statistical analyses that reflect the actual situation. These are considered the biggest obstacles to improving the sector due to their significant impact on resources and poor coordination between supply and demand, as clarified by decision-makers in the current questionnaires which filled by them. With the presence of Geographic Information System (GIS) technology, which represents a critical nerve in forming smart management for infrastructure networks, it is imperative to include mechanisms and standards of GIS and its modern applications in managing the energy sector. The current research aims to formulate standards and an executive framework to enable GIS mechanisms to manage the energy sector intelligently, ensuring its sustainability. In conclusion, implementing smart management of energy networks using ArcGIS Pro's "utility networks module" requires adherence to various criteria, which will be presented in detail in this study. These include sustainability, efficiency, maintenance response capabilities, security, integration, Real-time monitoring and controlling, analytical capabilities, and effective communication. By meeting these criteria, organizations can optimize energy network operations, enhance sustainability, and improve overall performance in the era of smart energy management.

***Keywords*:** Smart Management of Energy Networks, Geographic information system, ArcGIS Pro (utility networks module), Sustainable Energy.

INTRODUCTION

The infrastructure sector is one of the most important sectors affecting the sustainability of urban communities in Egypt. The infrastructure and its sector in urban communities is composed of several groups of networks that represent the fundamental nerve of all cities, such as:

- The energy sector (generation networks, transport networks, distribution networks, consumers);
- The water supply sector (degradation networks, treatment networks, transport networks, consumers);
- The sanitation sectors.
- The natural gas and petroleum supply sector.
- The telecommunications and Internet sector.
- Other sectors, such as the sensor network, cameras, the Internet, etc.

According to the results and indicators produced by the Egyptian Ministry of Electricity and Renewable Energy and in cooperation with the Egyptian Council of Ministers, the energy sector will have the highest annual growth rate by 2025, at 17% of the total growth of the leading infrastructure and infrastructure sectors, and is expected to increase by one year (Ministry of Electricity and New and Renewable Energy, 2022).

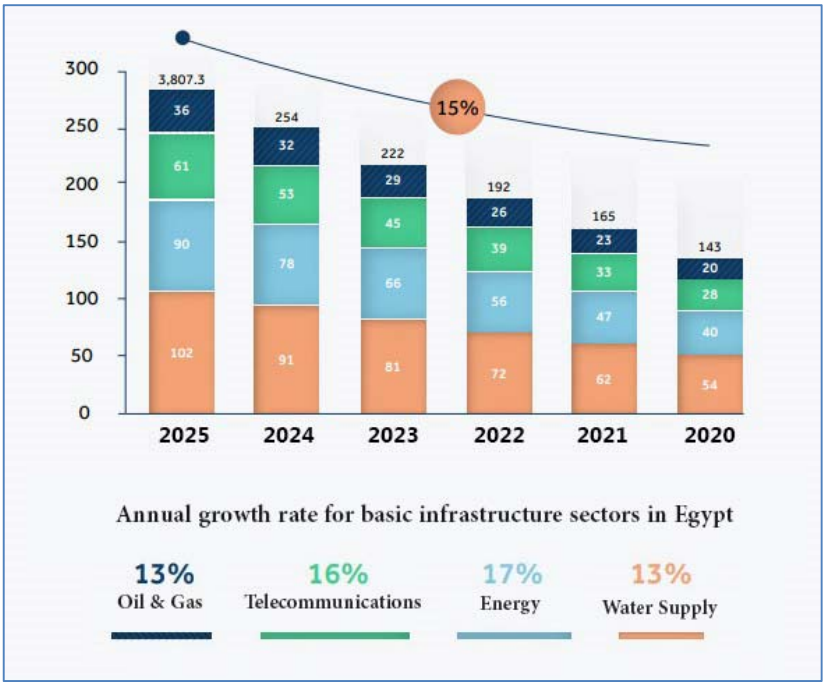

Fig. 1 Annual growth rate for basic infrastructure sectors in Egypt. Source: Ministry of Electricity and Energy, 2020.

As was noted recently, the energy file in Egypt does not depend only on resources but, perhaps to a greater extent, on the policies, procedures and plans pursued by the government and the integration of modern technology and digital transformation into smart energy management. (Arafa, 2022)

Egypt Vision 2030 also aims to build a competitive, balanced and diversified economy (Arafa, 2022) within the framework of achieving sustainable development goals. Renewable energy and smart management play an important role in this. However, there are some of the challenges and problems affecting the Egyptian energy sector. These include:

- The problem of increasing demand for energy that is not compatible with production rates at present, as the current demand exceeds production rates by an amount equivalent to about 15.6% in all energy consumption sectors, and the absence of digital control and follow-up linked to central databases on consumers (Reports of the Ministry of Electricity and Energy, 2020).
- Increased rates of energy loss through networks. This reason is due to the deterioration of networks, the absence of effective periodic maintenance of the network, and the lack of interest in smart digital management of networks. (Mousa, 2019)
- The absence of intelligent electronic monitoring and monitoring systems on networks affects the efficiency of energy access in its stages from production to consumption (Ehrgott & Kuyucak, 2018), and also the absence of control

mechanisms for consumers, and this directly affects all energy management in Egypt intelligently and sustainably (Mousa, 2019)

- Failure to fully exploit GIS Geographic information technology systems in managing the energy sector at the republic level to improve work performance in this sector and failure to implement the idea of national visions in digital and technological transformation.

GIS Technology and especially ArcGIS Pro Utility Networks provides many benefits for the intelligent management of energy networks (Fig. 2). It enables real-time monitoring, enhanced asset management, improved network connectivity, efficient workflow, seamless integration with other systems, and advanced analytical capabilities. By leveraging these benefits, organizations can optimize power grid operations, improve reliability, and enhance overall performance ((IEA), 2021).

Fig. 2. Benefits of Geospatial Solutions, on various stakeholders in the energy sector. Source: author based on ESRI: The Business Value of the Utility Network, 2021.

Research problem

According to what was previously mentioned, and the extrapolation of the current situation of the energy sector in Egypt it became clear that the problem of the energy sector lies in the management processes of that sector, and that it suffers from a group of problems, and smart management mechanisms must be included to manage energy networks in various operational stages.

Research goal

This research proposes the use of "geographic information systems technology" as one of the most important tools that facilitate the process of smart management of the energy sector. Also, to formulate criteria and an executive framework to get benefits from applying GIS mechanisms in the intelligent and sustainable management of the energy sector in Egypt.

METHODOLGY

Previous studies and reports on national agencies in the field of energy had been used to determine:

- the energy problem (Electricity network) in Egypt, its dimensions, and its impact on environmental sustainability.
- the role of smart management in the energy sector in Egypt.
- benefits of the ArcGIS Pro and the utility network module.
- Mapping between Energy problems in Egypt and Geospatial solutions through ArcGIS Pro "Utility network module to enable smart management for this sector

Also, a set of questionnaires was designed to evaluate executive Criteria by decision-makers. These Criteria were tested and their efficiency was determined by taking the opinions of those concerned within the Egyptian Ministry of Electricity and Energy, officials of the electricity sector administration, and officials of electricity distribution companies. The sample consisted of about 150 officials from the decision-makers who filled out the questionnaires about the efficiency of those executive Criteria that aim to activate smart management in the energy sector by enabling GIS Technologies.

RESULTS AND DISCUSSION

1. The energy problem (Electricity network) in Egypt, its dimensions, and its impact on environmental sustainability

Despite the importance of the energy sector in Egypt, it suffers from the absence of the role of smart management mechanisms, especially the absence of the role of using applications and modern technology, which affects ensuring the sustainability of development in the sector in the long term. The main problem of the energy sector is centred on several basic axes that directly demonstrate the impact of the absence of smart management and governance systems in managing the energy sector, according to what was conducted in the questionnaires and meetings with decision-makers in the Egyptian energy sector. These problems can be summarized as follows:

The absence of the role of smart management, digital follow-up and control over consumers. The absence of a digital monitoring and monitoring role for energy consumers in all their forms has led to a steady increase in the demand for energy in Egypt over the past decade, recording an annual growth rate that reached 43% in 2021, with the maximum value of loads approaching the installed capacity (Ministry of Electricity and Energy Renewed Authority, 2022).

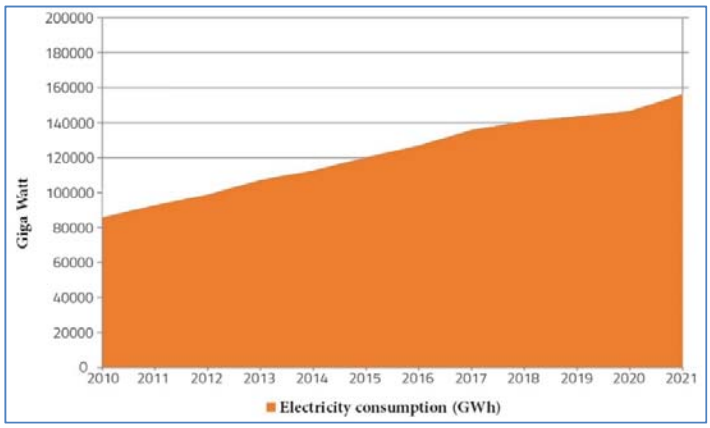

Fig. 3. Energy consumption rates from 2010 to 2021. Source: Electricity Holding Company (2022).

It was noticed from Figure (3) that the development of energy consumption rates in Egypt until they reached unprecedented growth rates in recent decades, reaching more than 43%, and we note the increase in demand for energy at present, which reaches more than 200 thousand gigawatts.

1.1.The lack of activation of spatial information technology applications and models and their impact on increasing the gap between demand and production

The absence of the role of spatial information technology applications and models and the absence of central databases for consumers causes the gap between demand and production to increase annually in Egypt until the gap approaches more than about 7% of production rates despite the Egyptian state's attempts to reduce this gap in recent years, as shown from the annual reports of the Ministry of Electricity. Also, more than 10% of energy consumption in Egypt is unknown where it is consumed. This is due to the lack of complete monitoring that includes all energy consumers in the form of central databases (Reports of the Ministry of Electricity and Renewable Energy, 2020).

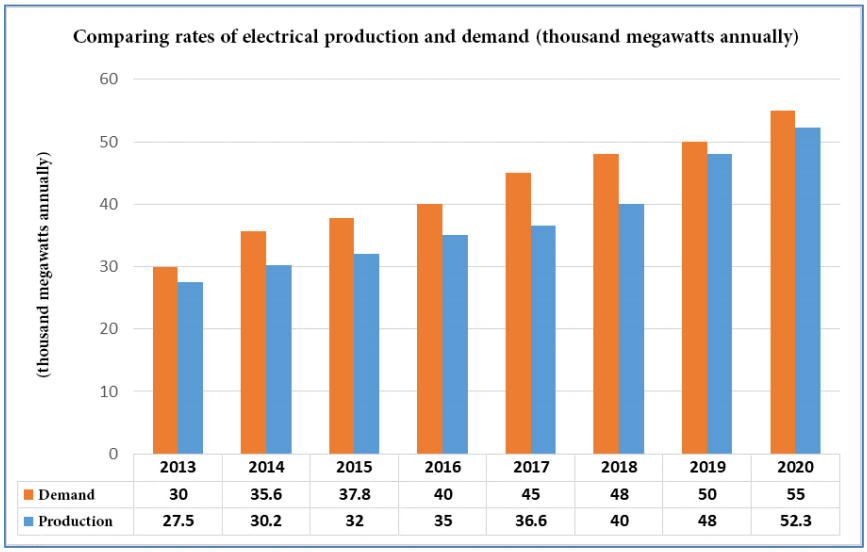

Fig. 4. Annual demand of electricity and the actual electrical production in Egypt during the period 2013-2020. Source: Ministry of Electricity and Energy (2020).

1.3Not integrating renewable energy sources into the energy production process and determining the appropriate times for operating them through modern technological information systems

Resources in the energy sector are considered to be of many forms and types, as natural resources (new and renewable energy sources), that can be exploited to fill the gap in energy production are also widely available in Egypt. The renewable energy sources include Wind Energy, solar energy, Hydropower, Tidal Energy, Geothermal energy and Biomass energy.

Integrating new and renewable energy sources not only has a positive impact on energy production in Egypt but also keeps pace with global trends to reduce global warming and reduce the carbon footprint: Green and renewable energy sources do not release carbon dioxide or other harmful pollutants into the atmosphere (NOAA, Carbon footprint is a way to reach low-emission cities, 2014).

1.4The absence of the role of regular maintenance and real-time monitoring of the performance of energy networks

Energy networks in Egypt suffer from poor management in the periodic maintenance phase of networks, which affects the networks and leads to their collapse (Mousa, 2019) The main factor affecting poor maintenance is the absence of systems for monitoring and managing network assets and the lack and absence of central databases containing network assets and their status. Also, the absence of real-time monitoring of the networks' performance affects them negatively and does not give a true picture of the network's performance, which also affects them.

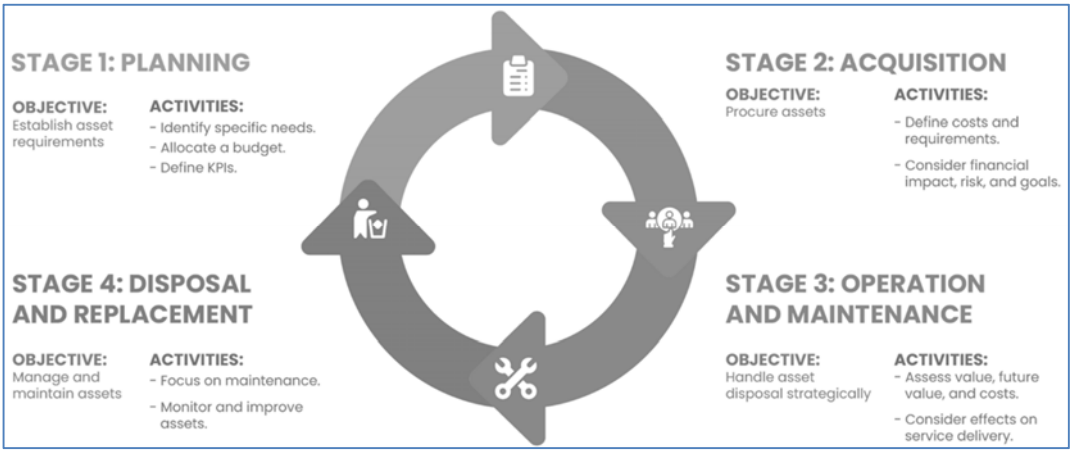

Fig. 5. The Life Cycle of Network Assets. Source: author.

It is clear from Figure (5) that at every stage in the Life Cycle of Network Assets the role of smart network management is absent, and this affects the next stage.

2.The role of smart management in the energy sector in Egypt

2.1 Smart Management Definition

Smart management refers to the use of advanced technologies, information technology, and data-driven strategies to improve the efficiency of various processes, systems, and services in different fields (Kumar, 2018). This approach involves the integration of information and communications technology (ICT) to collect, analyze and act on relevant data in real-time. The primary goal of smart management is to make informed decisions, enhance operational performance, and achieve better results. Therefore, we propose using smart management to deal with the problems facing the Egyptian energy sector.

In the context of an energy network, smart management refers to the application of advanced technologies and data-driven strategies to optimize the generation, distribution, and consumption of electrical power. It involves the integration of digital communication, control systems, and intelligent analytics to enhance the efficiency, reliability, and sustainability of the entire electricity infrastructure. The goal is to make the electricity grid more responsive, adaptable, and capable of meeting the demands of modern energy systems (Kumar, 2022). The different dimensions that Smart management can deal with to support the Energy sector are shown in Figure (6).

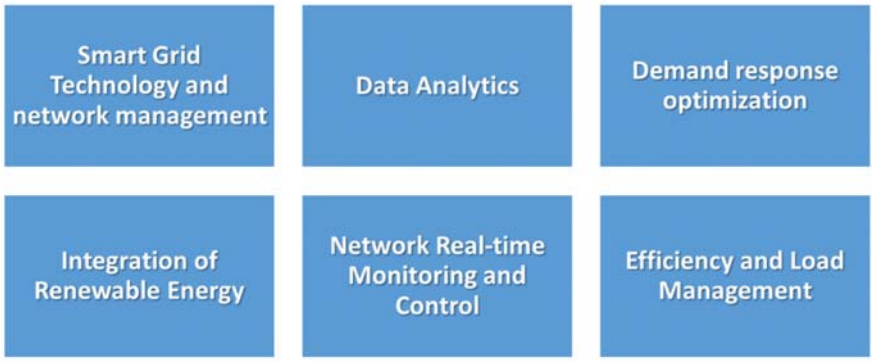

Fig. 6. The different dimensions that Smart management can deal with to support the Energy sector: Source: author.

2.2 Smart management mechanisms to support the energy sector in Egypt

Smart management can support the energy sector in Egypt by providing many mechanisms and technologies to enhance the efficiency of using energy resources and improve the performance of the electrical network. The following are some mechanisms that can contribute to supporting the energy sector in Egypt:

- Enabling smart grid technology. (Alam & Stojanovic, 2019)
- Electrical grid optimization techniques to improve the transmission and distribution of electricity. (Alam & Stojanovic, 2019)
- Use smart metering and control systems to react in real-time to network disturbances. ((IEA), 2021)
- Data analysis using artificial intelligence.
- Use data analysis and artificial intelligence to understand patterns and improve network performance. (Kumar, 2022).
- Providing accurate forecasts of consumption and energy generation and analyzing demand and production.
- Analysis, modelling and documentation of energy network assets, using geographic information systems (GIS). (Kumar M. a., 2022)
- GIS software helps all the different stages of planning and designing the network and documenting this in central databases.
- GIS can provide a great option for spatial analysis that can be used in managing energy networks.
- GIS can provide the full ability for organizations to manage energy network assets.
- Integration analysis with new and renewable energy.
- GIS plays an important role in the maintenance and emergency management of energy networks.
- GIS enables decision makers to obtain real-time information in monitoring the network, due to the high ability to integrate with various systems and technology used in the energy sector. (ERSI, 2021)
- Monitor and analyze supply and demand. (ERSI, 2021)

2.3 Geographic Information Systems (GIS) capabilities to support smart management in the energy sector

GIS can play a crucial role in the energy sector management by providing spatial analysis and visualization tools (Fig. 7). The following are some capabilities of GIS in the energy sector (Malczewski,, 2006):

- Site Selection and Planning
- Resource Assessment
- Infrastructure smart Management
- Emergency Response and Maintenance Management
- Grid Planning and Optimization
- Decision Support

Many companies provide software and geographic information systems services, and the most important of these companies is ESRI, which has been providing geographic information systems services for more than forty years and has provided many specialized products in that field, the most important of which is ArcGIS Desktop & ArcGIS Pro.

Fig. 7. GIS Applications General Capabilities: Source: author

ESRI has worked to develop GIS software to serve utility networks more powerfully and effectively. The advanced capabilities of ArcGIS Pro and the utility network module are shown in Figure (8).

Fig. 8. The advanced capabilities of ArcGIS Pro and the utility network module: Source: author.

3.Benefits of the ArcGIS Pro and the utility network module

The ArcGIS Pro and the utility network module has recently begun to play a major role in the planning, design, and management of infrastructure networks through many of the

capabilities provided by this software as shown in Figure (8). It is considered the most powerful in the field and on the market. (ESRI, 2022)

Through these capabilities, this model provides many benefits to infrastructure networks, users, and decision-makers like:

1. Benefits for Network Planning, Design and Engineering
2. Benefits for Operations and Maintenance Management
3. Benefits for Asset Management
4. Benefits for Customer Care

3.1Benefits for Network Planning, Design and Engineering

These are shown in Figure (9). The utility network optimizes designs 3D, direct connection with on-site personnel, and consuming web services save material and labour costs. Designs can be adjusted in real time to calm regulators and citizen. Editing has built-in rules that prevent errors from the start. When designs are accurate, as-built changes are fewer. As-built happens in real-time. This eliminates costly backlogs of un-posted work orders. Finally, great designs create safer projects, reducing accidents. (ERSI, 2021).

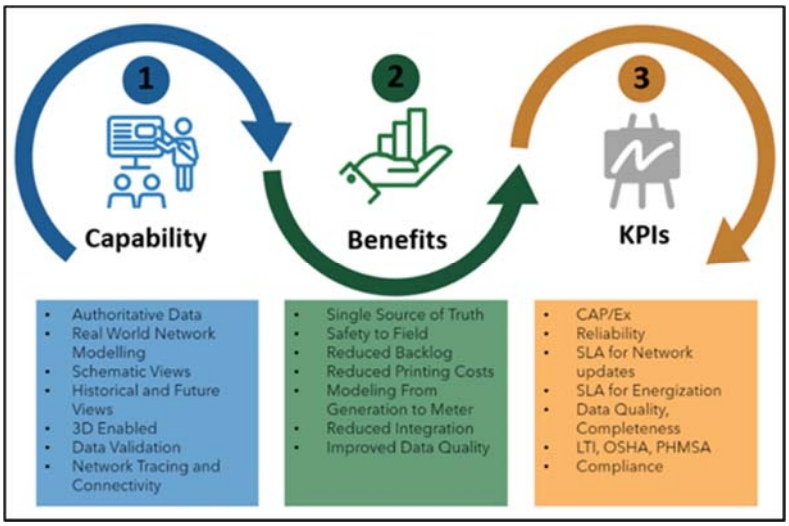

Fig. 9. Utility network module Capability, benefits and KPIs for Network Planning, Source: author based on ESRI: The Business Value of the Utility Network, 2021)

3.2Benefits for Operations and Maintenance Management

These are shown in Figure (10). Network management in ArcGIS accumulates an understanding of operations. When users pull together the work, people, and real-time data and consider them they get a complete operational picture with everything they need to run the system well - today and into the future.

Those capabilities deliver valuable benefits to the organization. When workers on-site have the same information as dispatchers, they will be safer. Workers that have access to real-time sensor data, and analytics to aid them in service restoration will be more efficient. Network analytics grant workers the opportunity to tune budgets and supplemental requests (ERSI, 2021)

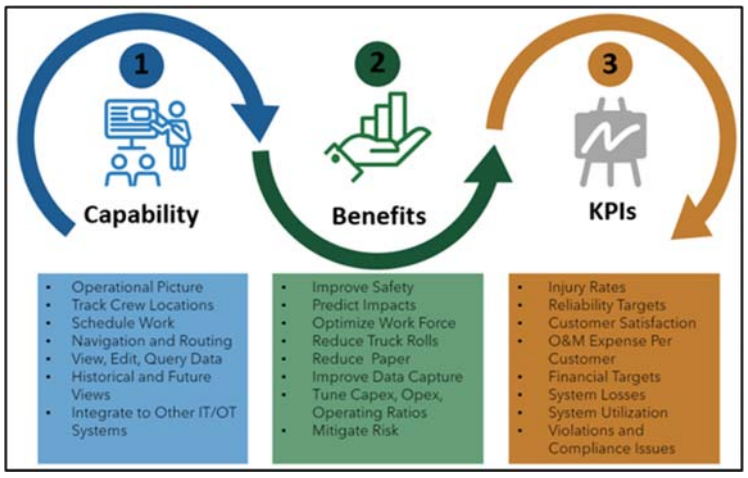

Fig. 10. Utility network module Capability, benefits and KPIs for Operations and Maintenance Management. Source: author based on ESRI: The Business Value of the Utility Network (2021).

3.3 Benefits for Asset Management

Asset management requires high data quality. It also requires that the data is captured on-site and communicated immediately to the enterprise. The utility network is mobile-enabled. Employees can take data to the job site. They see the most current data. They update it. It goes directly back into the corporate GIS. Not only is that happening, but it's validating on-site. It ensures what users are entering is valid and accurate. It connects the right type of assets due to business logic and rules. (ERSI, 2021)

Asset lifecycle management is evolving from time-based maintenance into reliability-centred maintenance and financially optimized maintenance programs. Visualizing vulnerabilities, monitoring and validating risk advances the mission of asset management. It provides the tools to optimize the financial assessments.

The utility network module capability, benefits and KPIs for Asset Management is shown in Figure (11).

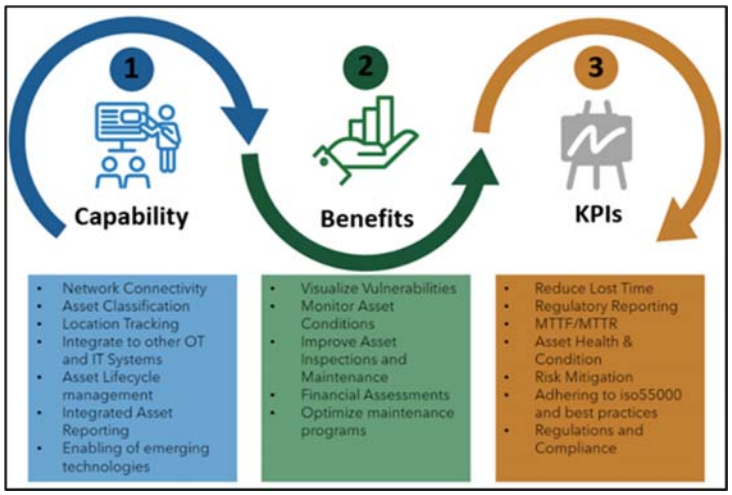

Fig. 11. Utility network module Capability, benefits and KPIs for Asset Management. Source: author based on ESRI: The Business Value of the Utility Network, 2021.

3.4 Benefits for Customer and User Care

Customer care can be thought of as the process of a utility seeking, connecting, serving, and satisfying the needs and expectations of those buying what it delivers. Delivery, of course, is via a network. And satisfying customers in many cases depends upon how well the organization understands the network, and how and where a customer is connected to it. (ERSI, 2021). The capabilities of self-service, network definition, customer locating, tracing, real-time updates and public situational awareness provide the foundation for outstanding customer care and service. The utility network module capability, benefits and KPIs for Customer and user are shown in Figure (12).

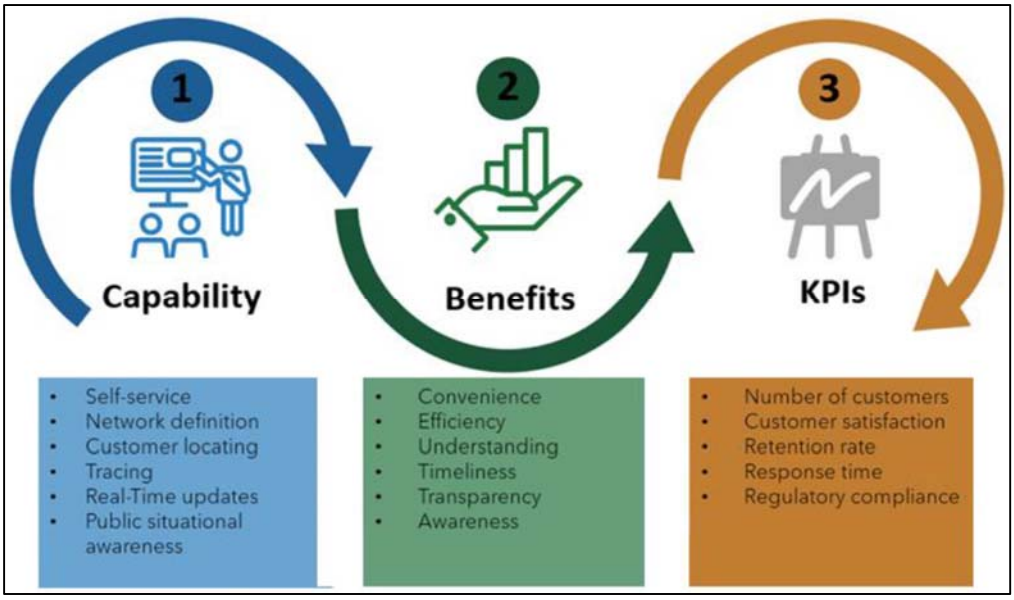

Fig. 12. Utility network module Capability, benefits and KPIs for Customer and User Care. Source: author based on ESRI: The Business Value of the Utility Network, 2021.

4.Mapping between Energy problems in Egypt and Geospatial solutions through ArcGIS Pro "Utility network module to enable smart management for this sector

It was obvious from Table (1) the main problems and challenges can face the Egyptian energy sector and how the geographic information systems through the utility networks model solve part of them to help in managing the energy sector.

From Table (1) we can identify the most important and appropriate planning, design, and administrative standards or criteria that can be applied to energy networks in Egypt to improve the efficiency of managing those networks, and these standards can raise the level of energy networks and bring them to the highest levels of environmental sustainability.

Table 1. The energy problems in Egypt and the role of ArcGIS Pro "Utility network module to enable smart management.

Common Energy Problems in Egypt	How to Enable smart management through an ArcGIS Pro "Utility network module"
The absence of the role of smart management, digital follow-up and control over consumers	- Building central databases for users - Modeling the components of the entire network - Converting traditional meters to smart meters - Connecting smart meters with user databases - Monitor users' actual consumption
The lack of activation of spatial information technology applications and models and their impact on increasing the gap between demand and production	- Building central databases for users and network components - Converting all traditional energy system management systems into geographic information systems - Integration of network monitoring systems with geographic information systems - Enable geographic information systems to monitor and follow consumption patterns to improve supply and demand for energy
Not integrating renewable energy sources into the energy production process and determining the appropriate times for operating them through modern technological information systems	- Using the capabilities of environmental analysis for solar and wind energy and determining the most suitable locations for resettlement - Enabling capabilities to improve the integration of renewable energy with traditional energy by analyzing consumption patterns - Monitoring renewable energy production through geographic information systems
The absence of the role of regular maintenance and real-time monitoring of the performance of energy networks	- Integration of the network's smart assets with geographic information system maps and providing precise locations of problematic assets in real-time - Providing real-time dashboards for network consumption and problems - Providing virtual reality and augmented reality visualizations to support field maintenance teams - Providing central databases that facilitate the process of managing assets in the network - Providing applications for maintenance management and field maintenance teams to facilitate the inspection process and respond to complaints

Source: author.

4.1 Criteria for implementing smart management of energy networks using ArcGIS Pro (utility networks module)

These include the following as shown in Figure (13):

- Enabling GIS to manage all network procedures. (ESRI, 2022)
- Convert all network information and drawings into a central geodatabase. (ESRI, 2022)
- Convert all network traditional assets into smart assets (meters – transformer – RMUs – etc.) (ESRI, 2022)
- Connect all network smart assets to the IoT Platform to store all assets feeds and use them later. (Zhang & Zhou, 2022)
- Build an assets management system to store all assets (condition – information – etc.) (Puranam, 2021)
- Integrate all using systems in the energy sector with GIS system. ((IEA), 2021)
- Build supporting applications for maintenance and field workers. (ESRI, 2022)
- Enabling real-time monitoring for (data flow, consumption and network assets status) through Dashboards and control rooms. (ESRI, 2022)

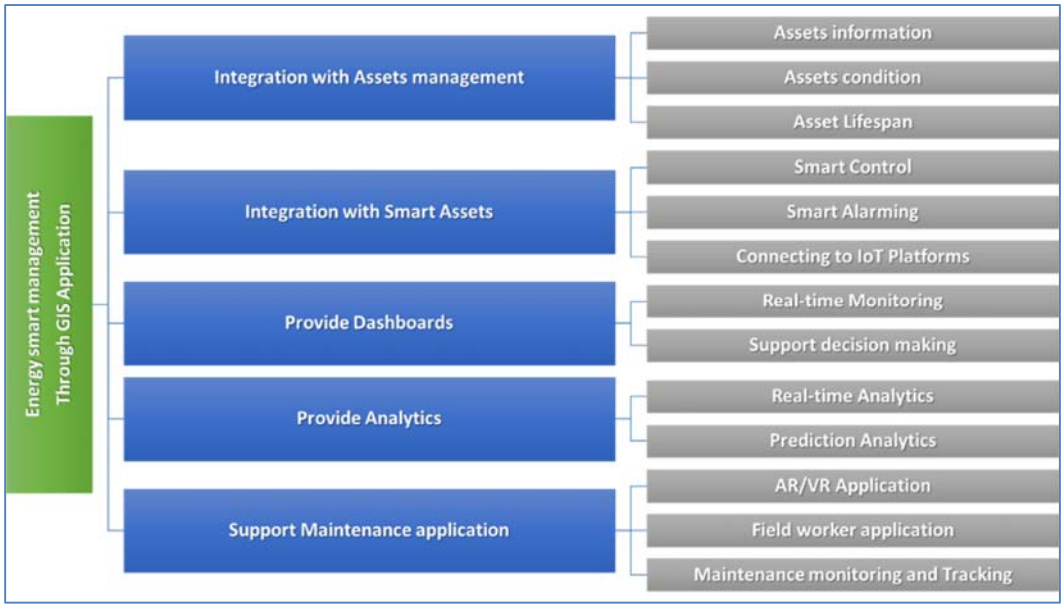

Fig. 13. Criteria for implementing smart management of energy networks. Source: author.

4.2 Evaluation of executive Criteria by decision-makers

Analysis the results of the questionnaires filled out by the official decision makers in the sector of electricity indicated the efficiency rates of those criteria required for implementing smart management of energy networks using Geospatial solutions through ArcGIS Pro (utility networks module) as shown in Table (2) and Figure (14).

Table 2. Percentage of the effectiveness of smart management Criteria using geographic information systems technology by decision-makers

#	Criteria for implementing smart management of energy networks using Geospatial solutions through ArcGIS Pro (utility networks module)	Percentage of effectiveness
1	Enabling GIS to manage all network procedures	87%
2	Convert all network information and drawings into a central geodatabase.	85%
3	Convert all network traditional assets into smart assets	86%
4	Connect all network smart assets to the IoT Platform	75%
5	Build an assets management system to store all assets	77%
6	Integrate all systems in the energy sector with the GIS system	75%
7	Build supporting applications for maintenance and field worker	83%
8	Enabling real-time monitoring through Dashboards and control rooms	84%

Source: author.

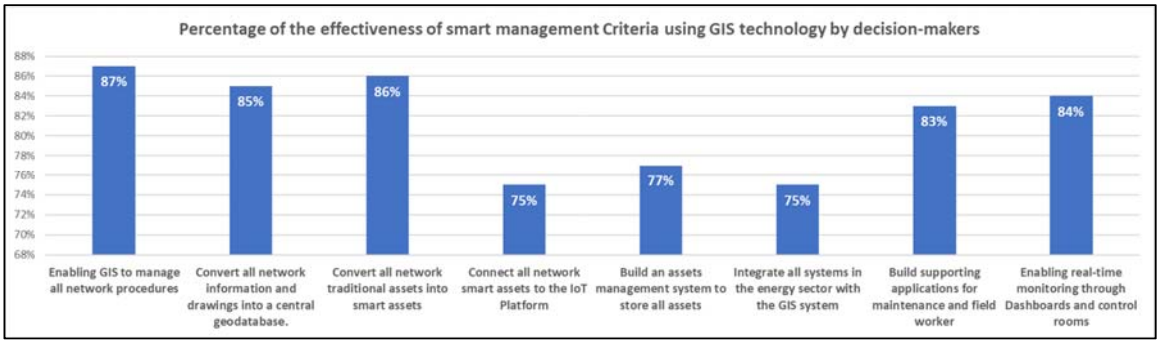

Fig. 14. Percentage of the effectiveness of smart management Criteria using geographic information systems technology by decision-makers

Based on presenting these mechanisms for community participation and taking their opinions through questionnaires, they explained that they prefer to use geographic information systems as the best solution for smart management of the energy sector due to the capabilities that were presented with a high ability to integrate with various systems and so on.

Through the previous evaluation, the Criteria will be arranged according to the priority of their use, from highest to lowest percentage, so that we can formulate the implementation framework according to importance. Also, it is possible to formulate executive Criteria for the smart management of the energy sector in Egypt, especially electricity networks, to reach the network with the best performance rates and improve levels of energy access to users.

4.3 Designing of Executive Framework for enabling Smart Management of Energy Networks using Geospatial Technology through ArcGIS Pro (Utility Networks module)

After arranging the previous standards according to their priority, the executive framework for those Criteria will be formulated, to enable smart management mechanisms for the energy sector and enable geographic information systems and their modern applications to manage that sector.

This proposed executive framework consists of a set of necessary basic tiers as follows:

- **Input Tier**: It is considered the tiered layer, which represents all the basic components of the Energy Sector (Electricity network) on which the final applications will be formed, which will serve the smart management of the energy sector.
- **GIS Tier**: This is the tier responsible for enabling geographic information systems and their applications to convert all inputs from their various formats into a unified format that can be dealt with in a central geospatial database.
- **Integration Tier**: This tier represents the two-way and one-way integration that will take place between geographic information systems and other elements in the system, apart from the integration between smart assets, asset management systems, smart control systems and other platforms.
- **Hosting Tier**: This tier is considered the main store and processing of all expected outputs that will be worked on during implementation, and it consists of large data stores to store readings of smart assets, Internet of Things platforms, and central servers.
- **Supporting Application Tier**: This layer represents the set of applications supported by geographic information systems that aim to facilitate the management of the energy sector intelligently. These applications are divided into (maintenance support applications - monitoring and follow-up support applications - smart control applications - smart analysis applications).

The Executive Framework for the Criteria that can be applied to electrical power networks in Egypt to achieve smart management is shown in Figure (15).

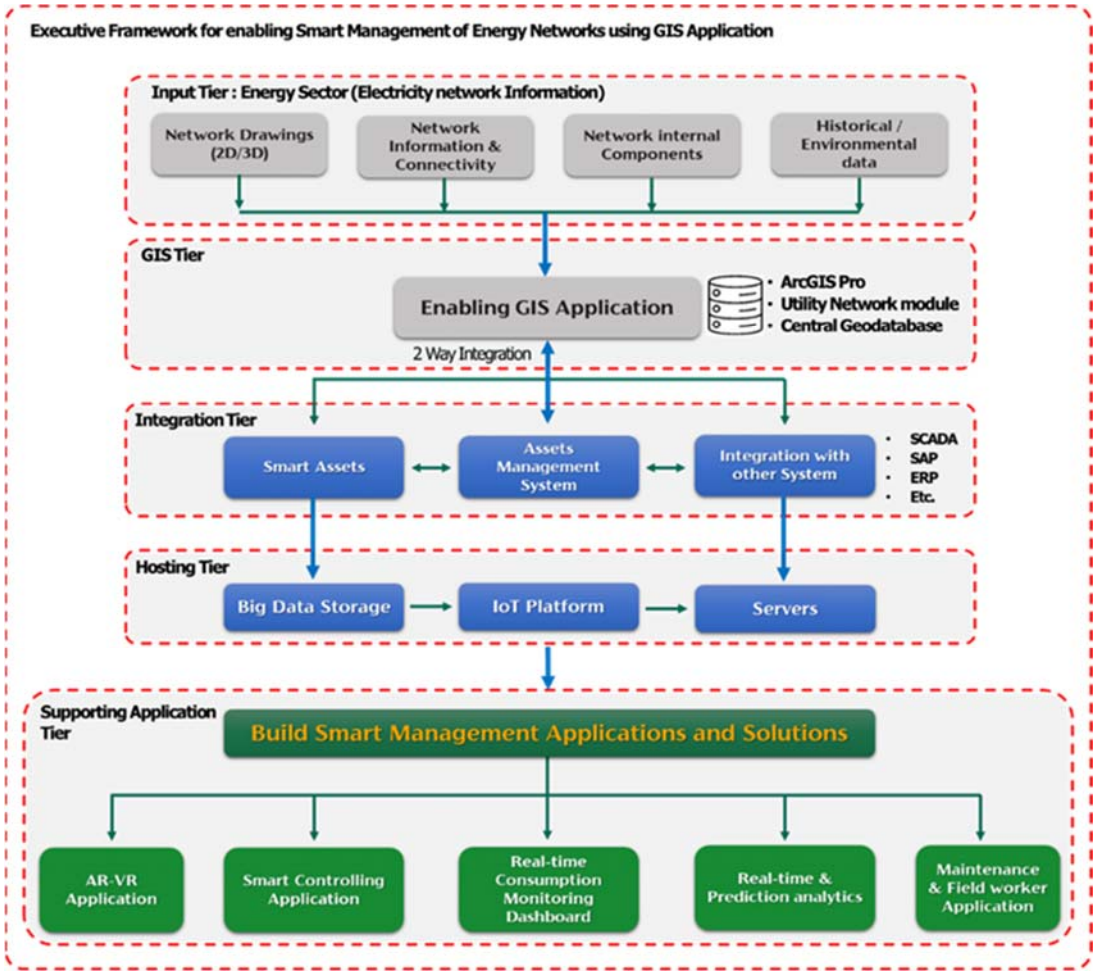

Fig. 15. Executive Framework for enabling Smart Management of Energy Networks using ArcGIS Pro (Utility Networks module). Source: author.

By applying the previous executive framework, it is possible to achieve smart management of the energy sector (electricity networks) to ensure the sustainability of that sector, the delivery of service with the best efficiency to users, ensuring the quality of distribution networks, matching demand with the available supply of the sector's current resources, improving the use of new and renewable energy, maintenance efficiency, and real-time monitoring of the status of networks.

Conclusions

The investigation delved into the foundational requirements and a strategic plan for adopting intelligent management systems within energy networks, leveraging the capabilities of ArcGIS Pro, and particularly its Utility Networks module. The research underscores the critical importance of geospatial technology in advancing the sustainability objectives within the energy sector. As energy networks become more intricate and interconnected, it's becoming increasingly vital to incorporate intelligent management systems.

Within ArcGIS Pro, the Utility Networks module stands out as a robust instrument, offering an all-encompassing structure to adeptly manage the elaborate web of assets and infrastructure that define contemporary energy networks. The success of its implementation hinges on a set of specific criteria, encompassing technological advancements, adept data handling, and strategic organizational approaches. It's evident that a holistic strategy, which includes cutting-edge spatial analysis, vigilant real-time monitoring, and forward-looking predictive analytics, is imperative for attaining the intended outcomes.

To wrap up, the guidelines and strategic framework outlined in this study are intended to act as a roadmap for entities that are looking to embed intelligent management within Egypt's energy networks through the use of ArcGIS Pro's Utility Networks module. As we pursue a future where energy is sustainable, the fusion of geospatial technology is fundamental. It empowers policymakers to unravel the complexities of our changing energy systems, setting the stage for a more sustainable energy infrastructure. In the end, we recommend applying this executive framework to the Egyptian case to ensure its efficiency and determine the efficiency of geographic information systems as an essential tool for achieving smart management of the energy sector.

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الإدارة الذكية لقطاع الطاقة في مصر باستخدام التكنولوجيا الجيومكانية

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المستخلص

تُعتبر مشكلة الطاقة في مصر من أكبر التحديات الاستراتيجية التي تواجه صناع القرار، إذ تُعد عائقًا يؤثر على الاستدامة البيئية واستدامة قطاع الطاقة في مصر. تتركز المشكلة، خاصة في شبكات الطاقة والكهرباء، في ضعف الإدارة وغياب آليات الإدارة الذكية عن إدارة القطاع، بالإضافة إلى غياب البُعد الجغرافي في ربط أصول الشبكة مع التحليلات الإحصائية التي تعكس الوضع الفعلي. تُعتبر هذه العوامل من أكبر العوائق أمام تحسين القطاع نظرًا لتأثيرها الكبير على الموارد وضعف التنسيق بين العرض والطلب، كما أوضح صناع القرار في الاستبيانات الحالية التي تم تجميعها. ومع توفر تقنية نظم المعلومات الجغرافية(GIS) ، التي تمثل عصبًا حيويًا في تشكيل إدارة ذكية لشبكات البنية التحتية، بات من الضروري تضمين آليات ومعايير نظم المعلومات الجغرافية وتطبيقاتها الحديثة في إدارة قطاع الطاقة. يهدف البحث الحالي إلى صياغة معايير وإطار تنفيذي لتمكين آليات نظم المعلومات الجغرافية من إدارة قطاع الطاقة بطريقة أكثر ذكاءاً، مما يضمن استدامته. في الختام، يتطلب تنفيذ الإدارة الذكية لشبكات الطاقة باستخدام "وحدة شبكات المرافق utility networks " في ArcGIS Pro الالتزام بمعايير مختلفة كما تم عرضها بالتفصيل في هذه الدراسة. تشمل هذه المعايير الاستدامة، الكفاءة، قدرات الاستجابة للصيانة، الأمان، التكامل، الرصد والتحكم في الوقت الحقيقي، القدرات التحليلية، والتواصل الفعّال. من خلال تلبية هذه المعايير، يمكن للمؤسسات تحسين عمليات تشغيل شبكات الطاقة، تعزيز الاستدامة، وتحسين الأداء العام في ضوء الإدارة الذكية.

الكلمات المفتاحية: الإدارة الذكية لشبكات الطاقة، نظام المعلومات الجغرافية، ArcGIS Pro (وحدة شبكات المرافق)، الطاقة المستدامة.