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A Bibliometric and Systematic Review on Identifying Criteria using AHP for location/site analysis of photovoltaic power plant installation

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Abstract

In the Sustainability era, the world is looking towards solar power plants, a significant alternative to the normal power supply systems because they help prevent the greenhouse effect and reduce the consequences of climate modifications. The prospective utilization of sun energy is greatly reliant on optimal sites choice for installation of plant. The optimal location identification is done by identifying and evaluating crucial criteria involved in this project. This study primarily aims to provide a literature review on crucial criteria identification and integration of AHP (Analytic Hierarchy Process) for solar energy plant installation. In the underlying study, the literature identified the criteria selected and prioritized through the AHP method. This research can help researchers understand the impact of AHP in site selection criteria identification and empirically work on the criteria found.

Keywords: Photovoltaic, Solar Plant, Literature, AHP (Analytic Hierarchy Process), Site Analysis

1. INTRODUCTION:

Solar energy is a valuable source to satisfy the rising global energy demand. The photovoltaic (PV) solar system life loop has four significant stages: analysis, execution/installation, operation and disposal (Pérez et al). As this breakdown plays a significant role in deciding on optimal fuzzy hybrid methodologies. The effective decision-making is highly required in opting for a perfect energy source, evaluating the performance of an energy source and infrastructure as a best fit for installation of such a source. Many studies including studies by International Energy Agency have attempted to find the amount of energy to be obtained from sun for meeting the climate change goals. It is said by IEA that by 2050, Solar energy would satisfy the World's energy needs. The Indian government has come up with so many strategies and subsidies to promote the Solar plants in India. A salient feature for accomplishing entire potential of Solar plant is the appropriate location selection for execution and this helps in achieving the slated goals of the government policy. Not only the studies in the context of India are limited, studies at international level has also become scare in recent years. With the recent emphasis towards solar energy by the government, the identification of criteria becomes a crucial factor. This study will provide guidance for the researchers to empirically analyze the location using the criteria derived for solar energy installation. A module of the solar power plant sector is to create, improve, and utilize the large-scale solar power plants that produce electricity using the sun.

In recent periods the solar energy industry has gained monumental growth due to the increased renewable energy demand and the government subsidies and legal assistance favouring the development of it. The CAGR of the solar power market is predicted to develop by 18.1% from 2020 to 2026, which would reach $344.7 billion. United States, Japan, China and India are the nations that lead the sector. PV and concentrated solar are the two primary forms of solar power plant technology. Solar power plant growth has been aided by numerous regulations and incentives, including tax credits, feed-in tariffs, and

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standards of renewable portfolio. These regulations assist the expansion of the sector and promote investment. Solar power plants has a low environmental effect as compared to fossil fuel power plants since they emit no greenhouse gases or pollute the air. Yet, there are certain environmental problems related with solar panel manufacture and disposal. Though it has many benefits and a support system to adopt, there exists a few challenges in adoption such as technical glitches, lack of regulations, financial problems, local engagement, lack of awareness on governmental support, usage of land, knowledge and awareness, business models underdevelopment (Saraji et al.,)

Studies conducted in developed markets have mostly used the Multi-Criteria Decision-Making Methods (MCDM) to find the weights for various parameters that would affect the location of the solar plants. Some of these studies have utilized the Analytic Hierarchical Process (AHP) to find the specific weights for the parameters affecting location of solar power plants (Aly et al., 2017, Fang et al., 2018). The Analytic Hierarchical Process (AHP) was first developed by Prof. Thomas L. Saaty in 1977 (Saaty 1980). From its introduction AHP has been used for finding solutions and decision-making for problems which are complicated. Since introduction, it has been deployed in numerous variant fields for analysis of user choice. AHP has three steps a) identifying the problem and building a hierarchy, b) comparative matrix creation and c) weight of distinguished parameters are determined

This study aims to identify the criteria derived using AHP from research papers for solar plant installation. This study recommends the crucial criteria for solar energy installation which is further useful in identifying site locations for installation across the World.

This paper contributes significantly to the three research questions

RQ1: To provide an insight into bibliometric analysis on location/site analysis for solar/photovoltaic implementation using AHP

RQ2: To provide insights on keyword analysis and cluster analysis for the location/site analysis for solar/photovoltaic implementation using AHP

RQ3: To identify the predominant criteria involved in location/site analysis derived through AHP for photovoltaic implementation.

Research Methodology:

3.1 Search strategy and Study selection:

The search was done by collecting literature through Scopus, Science Direct, ProQuest, EBSCO and Google Scholar. The preliminary strings are “Photovoltaic OR Solar AND Power OR Energy OR source AND Location OR site AND analysis AND AHP ”. The search keywords are used with Boolean operators such as “AND” and “OR”. OR is used to find documents that have any of the terms and AND is used to find only those documents that have all of the terms. The Data Mining was carried out in March 2024. A deep review of research articles on every subset of concepts provides insights into research gaps and guides for further research proceedings. To further improve the initial results and to extract relevant articles, certain inclusion and exclusion criteria were applied. Tabulation 1 illustrates the used criterion for refined search.

Tabulation 1: Illustration of Inclusion and Exclusion criteria

Criteria	Inclusion	Exclusion
Publication years	2012-2024	Before 2012
Subject Area	Business, Management and Accounting, Decision Science, Social Science and Multidisciplinary	Non-Management, Business topics
Article Type	Articles, Conference Proceedings, Reviews	Book Chapters
Language	English	Non-English
Access Status	Open	Restricted

The PRISMA method is used to derive the optimal literature serving the purpose.

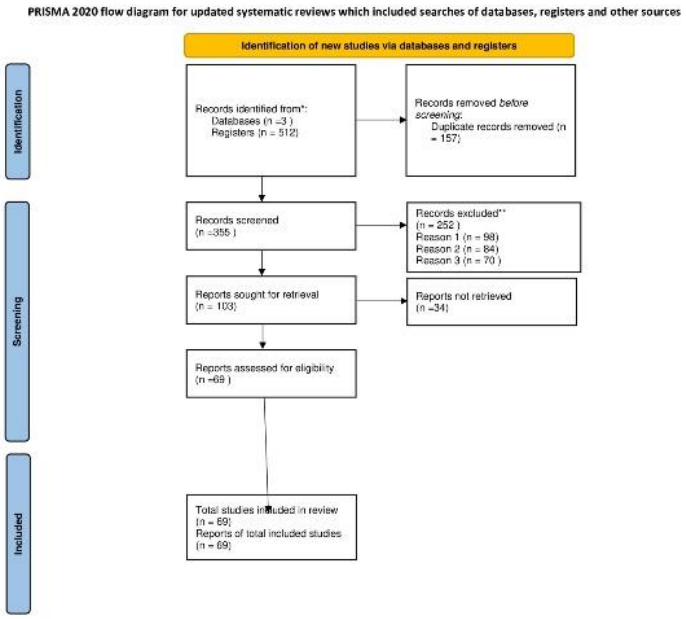

Fig 1. PRISMA Approach for study search and selection

3.2 Analysis/Synthesis of the study:

Post-selection based on the search strategy, the selected articles go through an intensive analysis. To break down the study, the MS Excel Spreadsheet was used where the data of the articles were filtered and uploaded. Later, the articles were evaluated in detail to extract the relevant articles that could serve the objectives. Graphical visualization is used to explain the bibliometric analysis Vosviewer is utilized to explain the keyword analysis and in an in-depth literature study helps derive the criteria involved in PV implementation.

3.3 Presentation (Reporting):

The outcomes were presented and discussed sequentially according to the Objectives. The discussion of the findings pointed out bibliometric analysis, keyword analysis and systematic literature review on consolidation of criteria involved in location analysis for PV implementation.

4. Analysis:

4.1 : RQ1: Bibliometric Analysis on Location Analysis for PV Installation

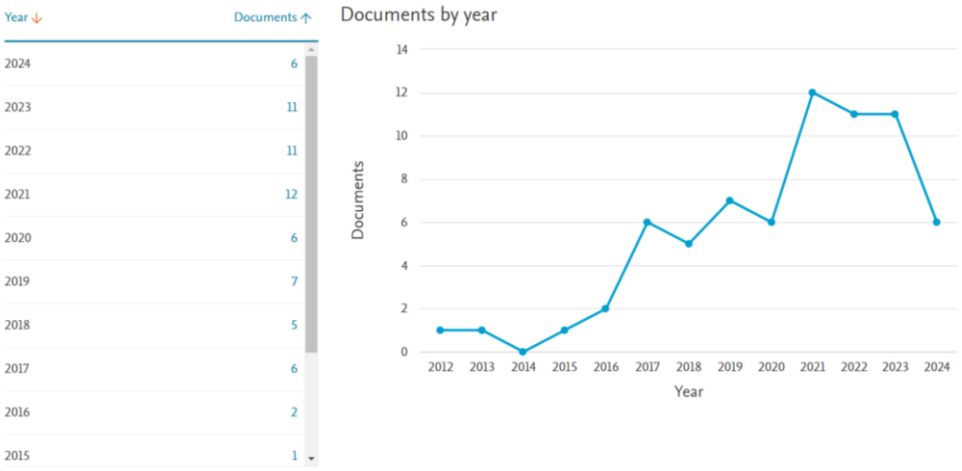

Fig 2 illustration of the publication rating by year

As can be observed from the graph the research on location analysis started increasing from 2014. 2014 was the largest year ever with 767 MWac brought online for concentrating solar power as per Solar Energy Industries Association (SEIA). So, naturally, the research on location analysis for solar power plants started increasing from the year 2014. Increasing demand from the industry for such analysis can be one reason. With so much installation happening, the research community would have started recognizing location as a problem in solar installation demanding a study about it.

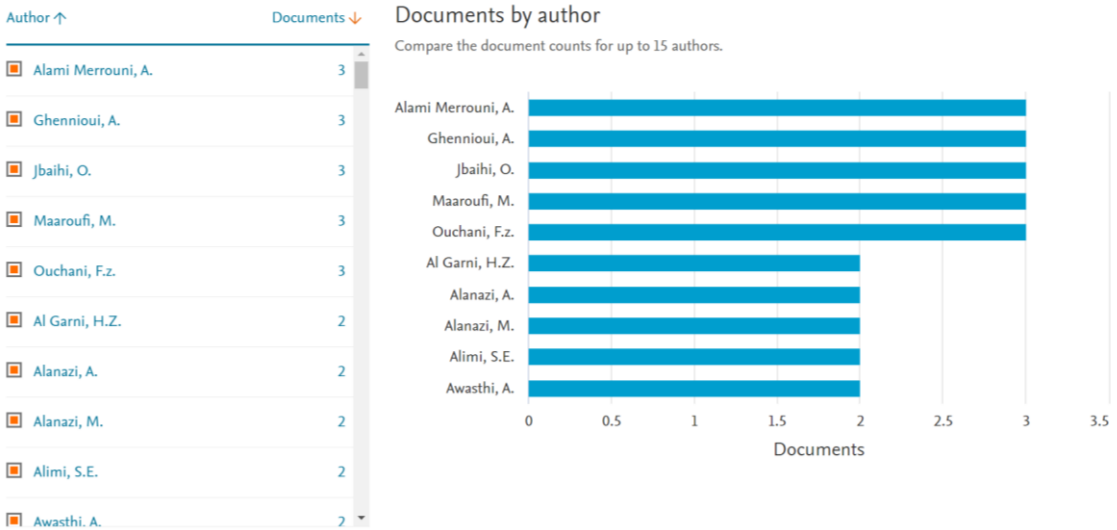

Fig 3 illustration of the publications by author

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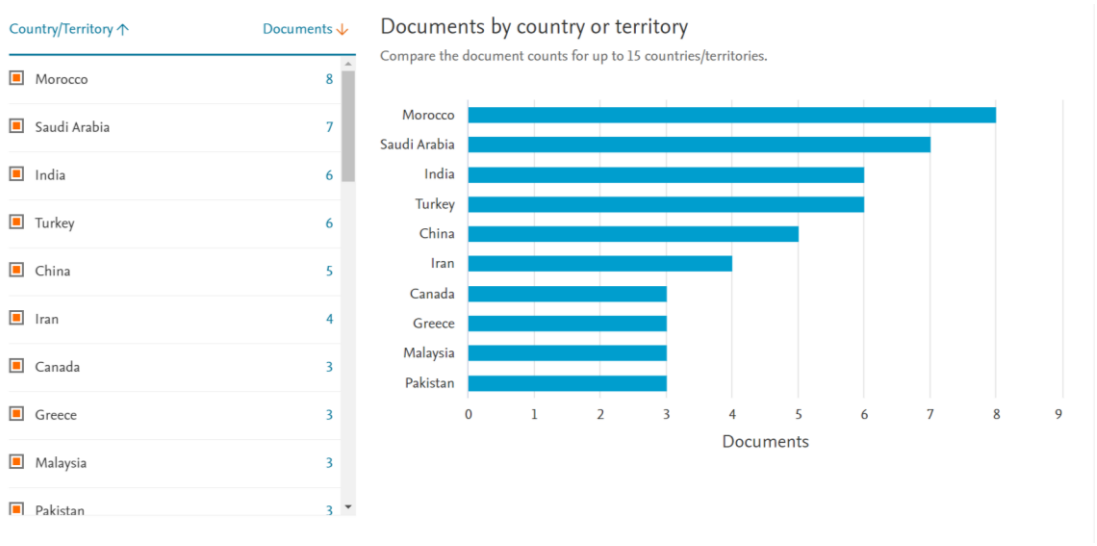

Fig 4 illustration of the publications by Country

The graph about the publications by country clearly corroborates other evidence. For example, Morocco launched one of the world's largest solar energy project way back in 2009 itself, with the aim of creating 2000 megawatt of solar energy generation capacity by 2020. In case of Saudi Arabia, in 2021, Saudi Arabia was getting 60% of its energy by burning oil. With increasing oil prices, Saudi Arabia wanted to decrease the dependence on oil. Ka-Care, Saudi Arabia's renewable energy agency announced in 2012 that by 2032, the Country would install 25 GW of solar capacity. In 2018, Saudi Arabia announced that by 2030, they intent to install 200 GW of solar capacity. India with 81 Gigawatt of installed solar capacity is the third largest producer as of 2024.

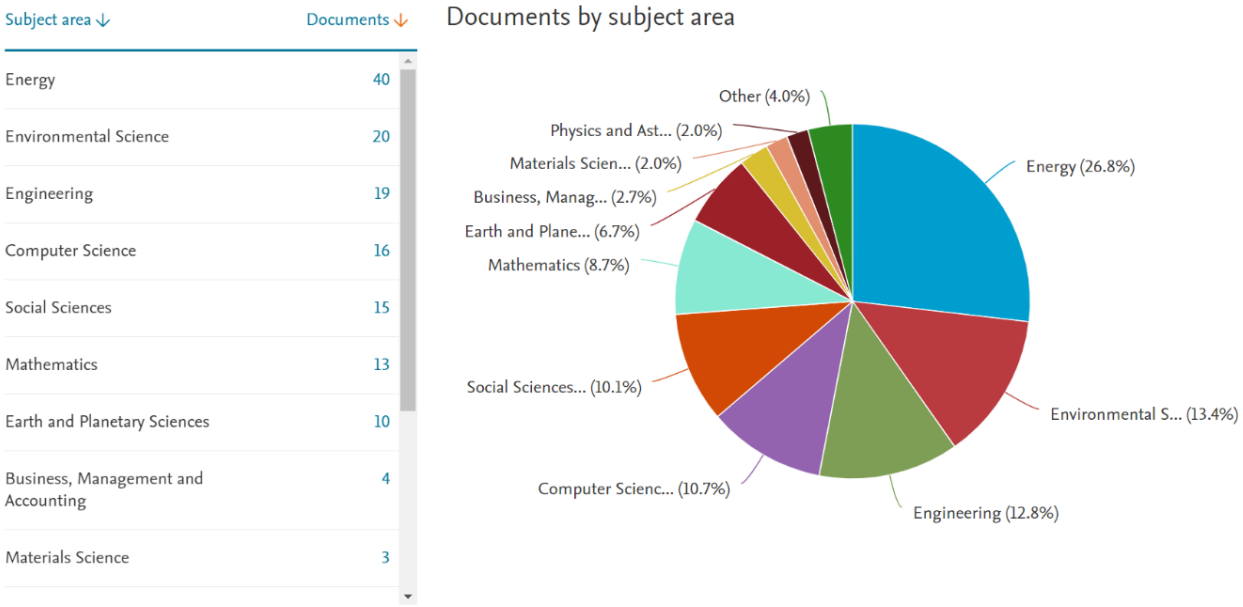

Fig 5 illustration of the publications by Subject Area

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From subject area graph it can be concluded that location analysis for PV module has invoked interest not only in subject areas like Energy, Environmental Science and Engineering. It has created interest in lot of other subject areas as well. The possible reasons could be the emphasis given by various governments all over the world, increasing concern for climate and most importantly, the potential for solar energy as a reliable renewable energy source.

4.2: RQ2: Keyword analysis on Location Analysis for PV installation:

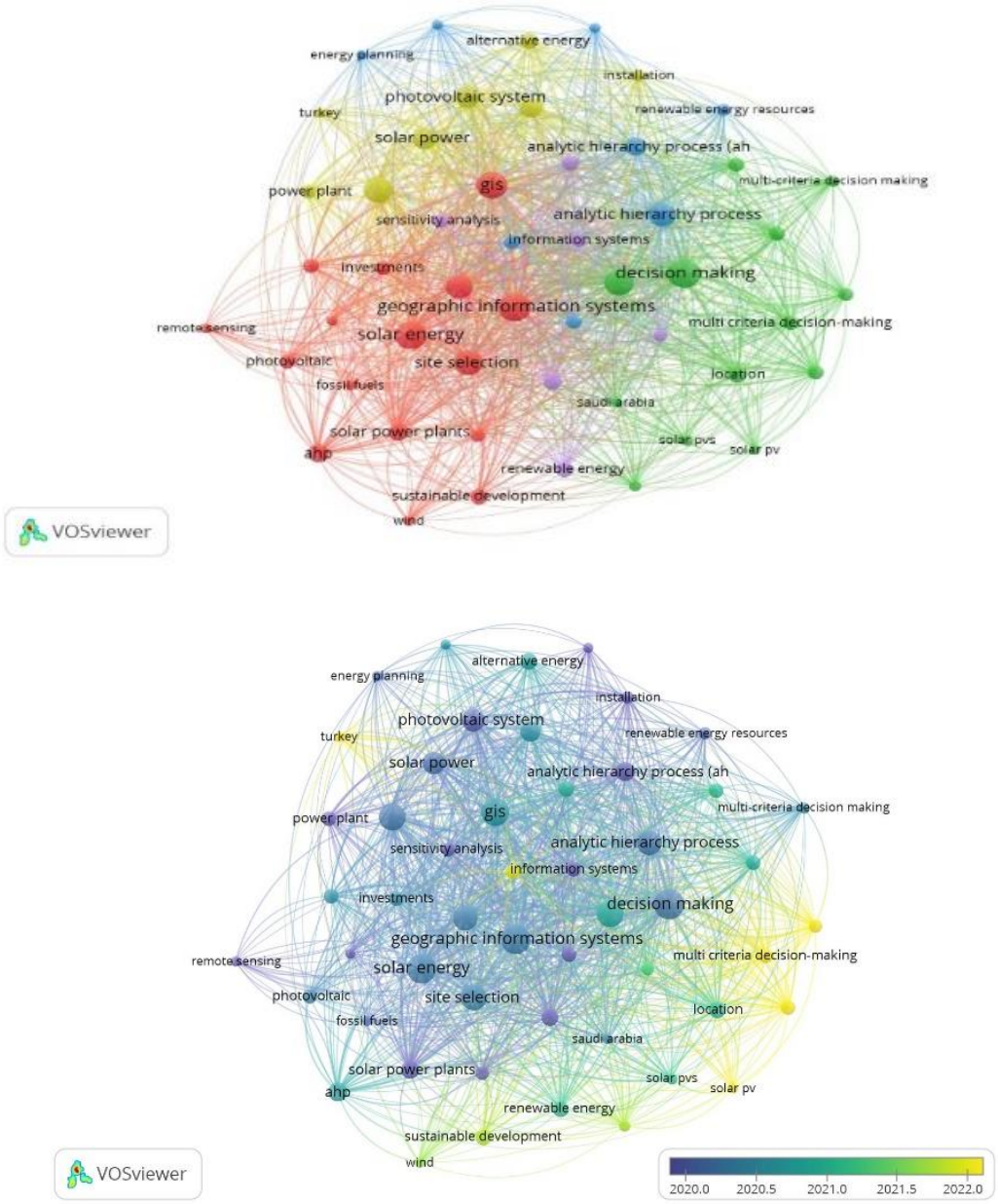

Fig 6 illustration of the general and years wise keyword analysis

The general and year wise keyword analysis shows “General Information Systems” GIS, occupying the central position. This shows that most of the research about location analysis for PV modules has used the GIS framework for performing the analysis. This shows the reliability and versatality of the GIS framework for conducting location analysis.

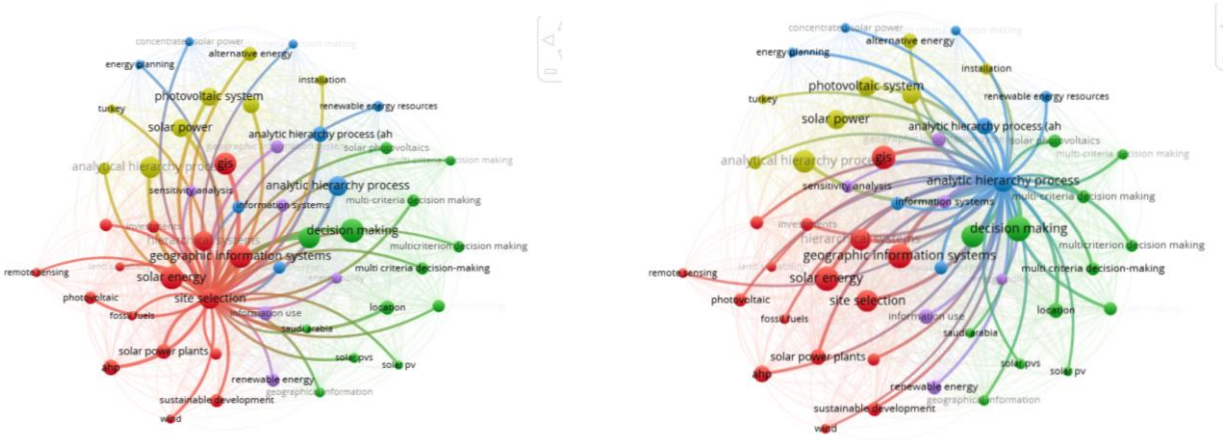

Fig 7 illustration of the keyword analysis for the terms “site selection” and “AHP”. Keyword analysis about AHP shows that AHP occupies central position in various analysis related to location and solar energy. This shows that AHP as a method is widely used for site selection for PV modules.

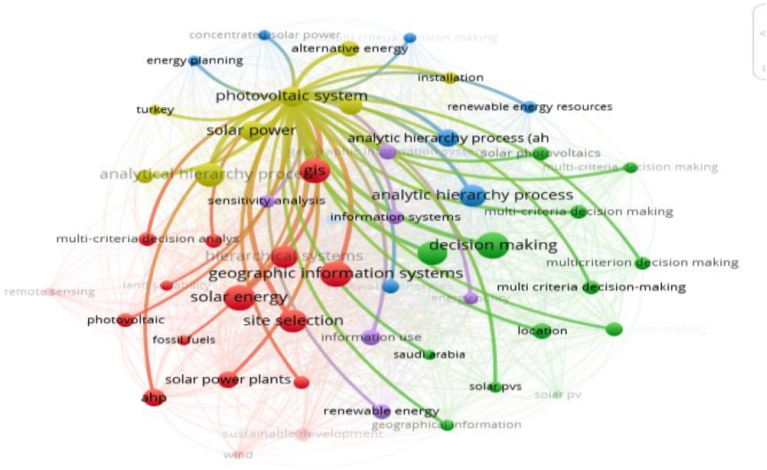

Fig 8 illustration of the keyword analysis for term “Photovoltaic system”

Keyword analysis about Photovoltaic system shows the significance of usage of Analytical Hierachy Process and Geographic Information Systems. This shows that most of the location analysis about Photovoltaic systems or solar plants is based on AHP and GIS.

From the keyword analysis the following can be inferred. Increasing research about site selection for solar plants in countries where governments adopted and promoted solar energy in a big way. The predominance of usage of Analytical Hierarchial Processing (AHP) and Geographical Information Systems (GIS) framework for research on location analysis for solar plants. Hence, if India were to

promote and adopt solar energy to reduce its dependence on fuel-dependent energy, a through research about location analysis used GIS and AHP is very much necessary.

Keyword Cluster Analysis:

The cluster analysis uses Association as the Normalization method. This analysis has come up with 5 clusters out of which the major 3 clusters were selected for analysis.

- Cluster 1: Fig 9 illustrates the cluster 1 with AHP as the primary attribute with a link strength of 143 and links with the 15 more data index.

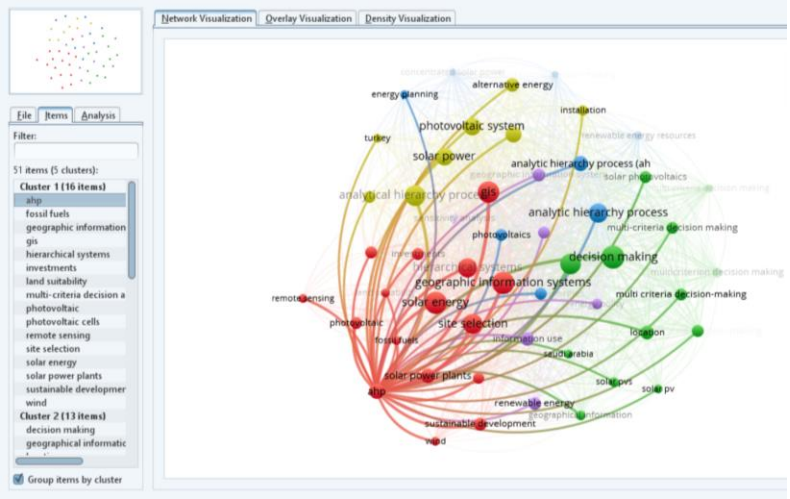

Fig 9 Cluster Analysis for keyword “AHP”

- Cluster 2: Fig 10 illustrates the cluster 2 with Decision - making as the primary attribute with a link strength of 454 and links with the 12 more data index.

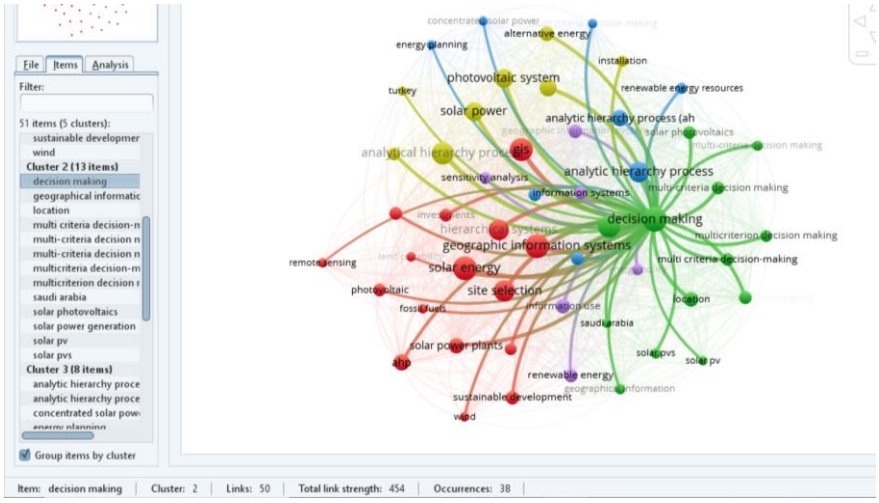

Fig 10 Cluster Analysis for keyword “Decision-Making”

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- Cluster 3: Fig 11 illustrates cluster 3 with Analytic Hierarchy Process as the primary attribute with a link strength of 297 and links with the 6 more data index.

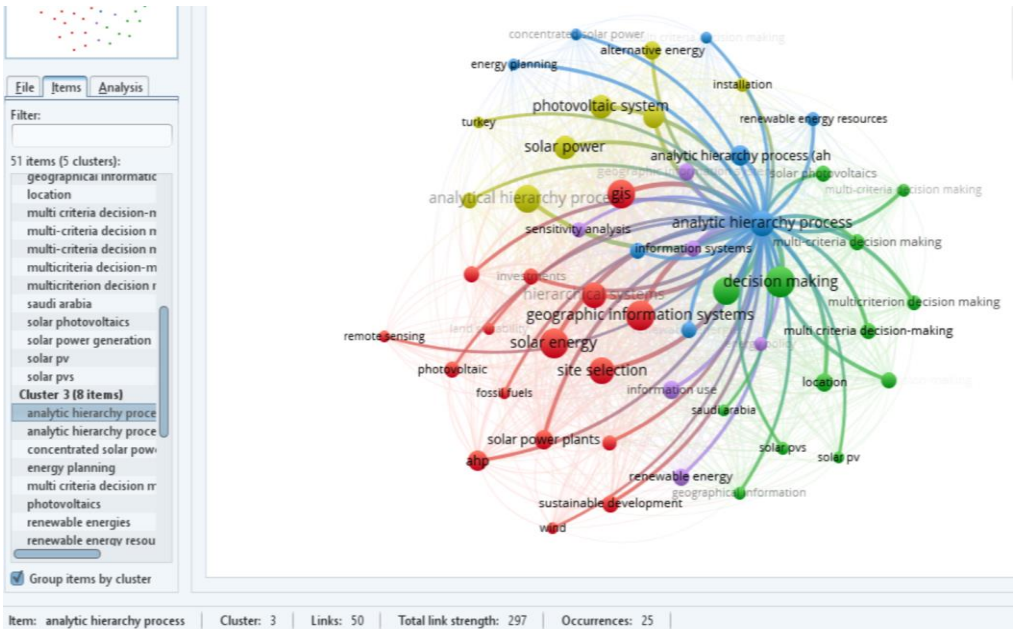

Fig 11 Cluster Analysis for keyword “Analytic Hierarchy Process”

4.3: RQ3: To identify the predominant criteria involved in location/site analysis derived through AHP for photovoltaic implementation.

Since AHP plays a predominant role in location analysis for PV Solar Power plant, the predominant criteria for PV Solar installation is retrieved through intensive literature review which utilized AHP as a tool.

AHP – Framework

AHP is a framework (Fig 12) for making decisions that can be used to evaluate the potential suitable sites for a PV power plant. AHP gives decision –makers the ability to rank criteria and compare the alternative’ performance in comparison to the criteria

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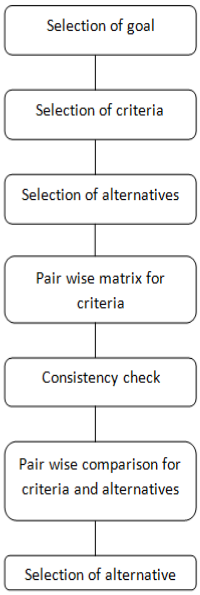

Fig 12 AHP Framework

Proposed Predominant Criteria:

From the literature review, Fig 13 explains the general criteria are huge in number retrieved which is shown as Optimal site selection criteria, right-hand side extending from “Finding the criteria”, from where the predominant criteria are derived from the literature which used AHP for criteria selection. The AHP tool application review resulted in 8 predominant crucial criteria that help in PV solar panel implementation is shown in the left-hand side extending from “AHP Technique”

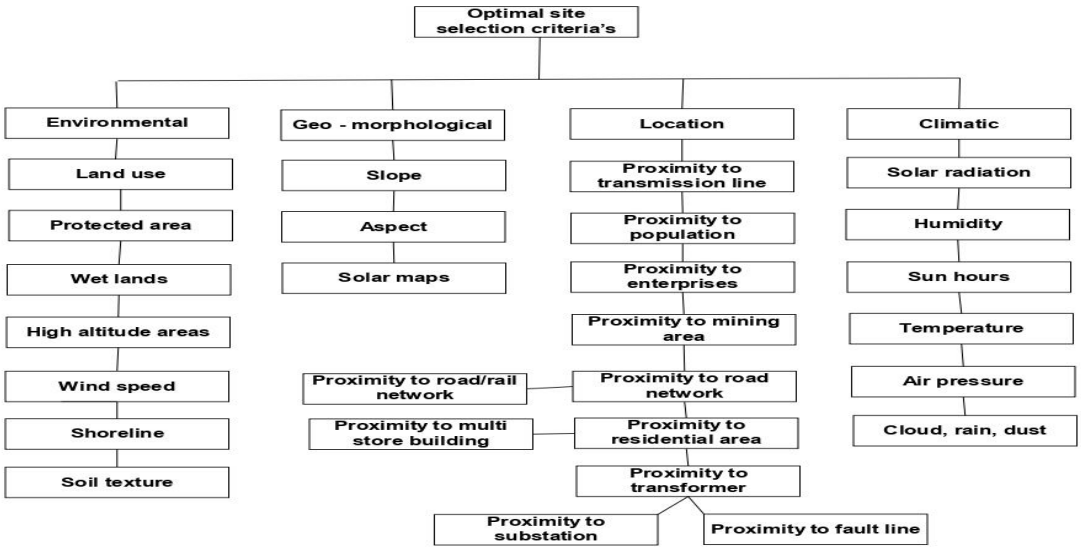

Fig 13 – General criteria for PV solar plant installation

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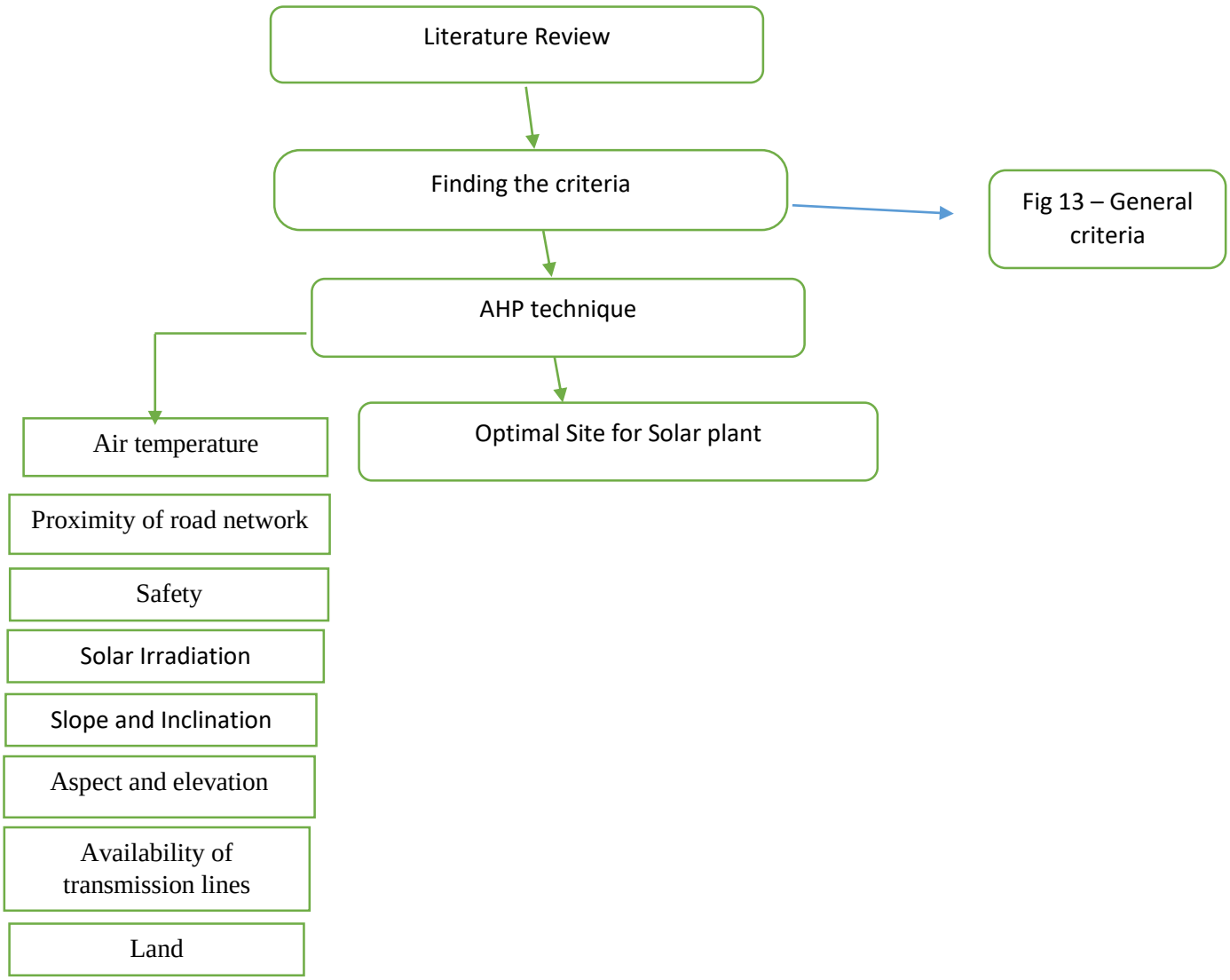

Fig 14: Predominant Criteria derivation by AHP literature for site selection

Table 2 provides the intensive literature that supports the predominant eight criteria on site selection using AHP for PV Solar panel.

S.NO	Criteria	Description	Author/Year
1	Solar Irradiation	The point on the earth's surface where solar radiation reaches is known as Solar irradiation. It is affected by geographical coordinates of the point, weather factors like humidity and temperature and the angle of sun. Since the the electricity generated by the solar plant is impacted by solar irradiation, it	Romero-Ramos et al., 2024 Bahaa Elboshy et al. ,2022 Orhun Soydan et al.,2021, R. Rios and S. Duarte, 2021, Mehmet Akif Günen,2021,

		is considered an important criteria. So, this criterion has to be accurately measured to decide on location of the plant.	Ephraim Bonah Agyekum et al.,2021
2	Slope and Inclination	Solar panels in flatter areas receive generate more electricity than in slope areas. So, slope has to be taken as a criterion for deciding location. Slope can be found from elevation maps.	Agyekum et al.2021, Bahaa Elboshy et al.,2021, Orhun Soydan,2021, SedaTürk et al.,2021, R. Rios and S. Duarte,2021, Mehmet Akif Günen,2021, Ephraim Bonah Agyekum et al.2021 Abraham Nebey et al.,2020, Ahmed Hassan et al.2020 Martin A et al., 2015
3	Aspect and elevation	The height at which the solar panel is located affects the amount of electricity generated. As we go to higher locations the thickness of atmospheric aerosols decreases, which results in solar panels absorbing more radiation. Elevations maps show the height of a location from Mean Sea Level (MSL).	Rane N L et al, 2024 Bahaa Elboshy et al.,2021, Orhun Soydan,2021, SedaTürk et al.,2021, R. Rios and S. Duarte,2021, Mehmet Akif Günen 2021 H. Ebru Colak, Tugba Memisoglu, Yasin Gercek,2020
4	Availability of transmission lines	Transmission lines are needed for transmitting the solar electricity generated by the plant. If the lines are closer then the transmission losses will be reduced and the cost of constructing transmission lines can also be reduced. So, availability of transmission lines is a criterion.	Bouramdane, A. A. (2024), Samak, Y. A. A. (2023), Bahaa Elboshy et al.,2021, Orhun Soydan,2021, SedaTürk et al.,2021, R. Rios and S. Duarte, 2021, Mehmet Akif Günen,2021
5	Proximity of Road Network	Proximity to roads is important because usually locations far from roads will not reachable, resulting in increased costs. So, how close a location is to road is taken as a criterion.	Mwizerwa, F., & de Dieu Hakizimana, J. (2021), Bahaa Elboshy et al.,2021, Orhun Soydan, 2021,

			R. Rios and S. Duarte,2021 Nebey, A. H., Taye, B. Z., & Workineh, T. G. (2020).
6	Land	Land is needed for installing solar plants. Open areas are more preferable for installing solar plants.	Islam, M. R et al., 2024 SedaTürk et al. ,2021 Nebey, A. H et al., (2020). SedaTürk et al.,2021, R. Rios and S. Duarte,2021,
7	Air Temperature	Even though solar plants run with radiation and more radiation will lead to more energy generation, high temperatures are not good for solar plants. The electrical components of the solar plant will be affected by the high temperatures. So, air temperature has to be taken as a criterion because it affects the efficiency of solar plant.	Islam, M. R et al., 2024 Wati, E., & Meukam, P. (2024) Romero-Ramos et al., 2023 Bahaa Elboshy et al., 2021 SedaTürk et al.,2021
8	Safety	Solar plant should not be in a place which is more prone to natural or man made hazards. Safety of the plant from such causes is also a criterion.	Islam, M. R et al., 2024 Seda Ozdemira and Gokhan Sahin,2018, Merve Akçay and Mehmet Atak,2018

5.Conclusion:

The key findings of this paper are from RQ1, the bibliometric analysis, the site analysis for PV solar power plant increased in the post-covid period, 2021. The highest country involved in Solar Power plant research is Morocco followed by Indonesia and India sequentially. Whereas, by subject area, social science contributes as 10.1% of literature and Business, Management possess just 2.7%, which shows that the research from the management and business perspective have a huge scope in the nearest future. RQ2 states that AHP and GIS are highly used in location analysis and in the year 2020, most of the research were performed using AHP for location analysis and 3 major clusters with AHP/Analytical Hierarchy Process and Decision-making were formed stating that in location analysis, AHP played a crucial role. RQ3 elaborates on the general criteria derived from the literature and from further scrutinizing on criteria derived through AHP tool had given 8 most vital criteria for location analysis namely, Solar Irradiation, Slope and Inclination, Aspect and elevation, Availability of transmission lines, Proximity of Road Network, Land, Air Temperature and safety. With the criteria derived, an empirical study could be performed for location analysis in India

6.Implications and Future Research Directions:

The findings of this paper could help Renewable energy companies to work analytically and target the appropriate audience at the perfect time. It also assists the researchers to go on for empirical analysis for different locations across the world. For future works, the criteria evaluation could be performed with other MCDM tools, Fuzzy hybrid methodologies and Machine Learning techniques. The efficiency of these techniques could be evaluated and finally, an empirical analysis for location analysis in India could be done.

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