Analysis and Ranking of Barriers in Development of Solar Power Using Interpretive Structural Modeling Method: Ethiopian Outlook

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Abstract

Ethiopia is quick evolving economy in Sub-Saharan Africa, and its industrial sector is growing faster. However, as a country level there is a significant electricity shortage. The country needs gigantic increments in capacity to meet the request of its quickly developing economy and population. Indeed in the event that endeavors are underway for renewable energy expansion in Ethiopia but stills solar oriented energy source are not highly utilized due to different problems that ruin its dispersion. On this basis, barriers of solar energy implementation in Ethiopia were identified utilizing different

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literature overview and experts' view in this investigation. Interpretive Structural Modeling (ISM) technique is adopted to recognize the interrelationship between the distinguished barriers. Matrice d'Impacts Croises-Multipication Applique' a Classment (MICMAC) method has too been utilized to sort the barriers based on dependence power and driving force. The results showed that four barriers related with economics, environmental and behavioral appear at the upper level in ISM configuration. A policy barrier shows up at the lowermost of model, and this is considered as the foremost powerful factor. Various solutions for relieving these distinguished barriers have moreover been recommended within the paper. Well understanding of these barriers can help the concerned stakeholders and policy creators to create proactive plans and fortification policies to increase the solar powered advancement in Ethiopia.

Keywords: Solar energy, interpretative structural modeling (ISM), MICMAC analysis.

1 Introduction

Ethiopia is a developing country placed in the horn of Africa with a surface area of 1,127,127 km^2 and a population of near 109 million in the end of 2019 [1, 2]. The country is confronting a serious problem of electric energy shortage, which is hindering its economic development and social advancement [3]. In 2018, only about 45% of the total population was accessed electricity [4]. However, the government of Ethiopia has launched an ambitious plan to attain universal electricity access by 2025, combining grid-tied and islanded supply option [5]. In order to attain the placed goal of country, investigation on the development of renewable energy sources could be very important. Among the clean energy sources, solar-based energy will become one of the perfect energy assets [6].

The sun is a typical star and it radiates energy radially from an compelling surface temperature of around 5760K, as electromagnetic radiation known as solar energy [7, 8]. The solar energy is harnessed in two main ways, either specifically with the help of solar PV cells through the production of electricity or solar collector devices harnesses heat by absorbing the sun rays [8, 9]. Most developing countries have good chance of harnessing the solar power [10]. Ethiopia is one of such countries which is well endowed with solar energy potential, and has irradiation potential ranges from

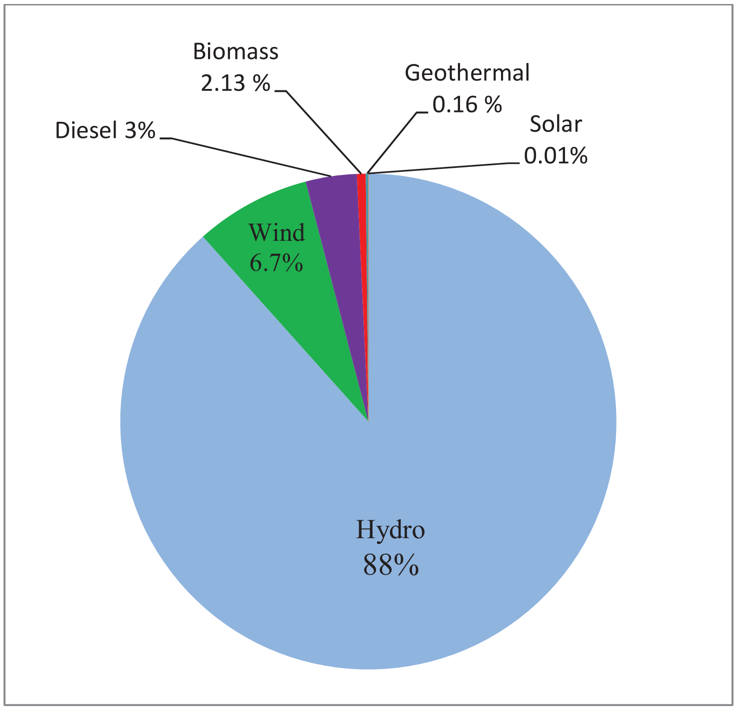

Figure 1 Ethiopia power generation mix (2018–19) [13, 14].

4.5 kWh/m^2/day to 7.5 kWh/m^2/day [11, 12]. This makes the best situation for the Ethiopian interior to exploit solar energy in the globe.

Even if the country has plenty of solar PV power generating capacity, from the total power generation the current share of solar PV technologies in the country remained so slow and the exploited proportion is less than 1% as shown in Figure 1 [13, 14].

There are various complexities which act as barriers for the growth of solar energy in Ethiopia, and during the past decades many research were conducted by different investigators to identify different barriers for implementation of solar energy technology in different countries of the world.

In [15], Kebede et al. illustrated the important role of policy intervention for quicker dispersion of solar PV systems in Ethiopia. In [16], Endale identified lack of consciousness by customers, low energy tariff of other energy source and absence of organized institutional structure as critical barriers for the development of solar water heaters in Ethiopia. In [17], Guta presented the importance of education and poverty reduction policies for the elevation of household uptake of solar power technology in the country. In [18], Daniel et al. considered reliable and transparent information as barriers to the adoption of residential solar PV. In [19], Cho et al. pointed out that the positive correlation between education and income affects the growth of solar PV in the Pacific Northwest USA. In [20], Gebreslassie found that shortage of investment and skilled workforce is the main obstacle for developing solar and wind power technologies in Ethiopia. In [21], Kizilcec et al. pointed out that the institutional frameworks and incentives required to rise the development of solar home system are influential to efficiently develop solar home system in Sub-Saharan Africa. In [22], Khan found that economic and lack of technical provision related to maintenances played a considerable role in developing country to solar home system growth. In Ref. [23], lack of financing scheme and weak government support is recognized as a constraint for the implementation of solar home system in developing regions. In [24], Kebebe identified lack of awareness and lack of finance as obstacles for the growth of solar PV in Ethiopia. In [25], Dagnachew et al. explored the result of improper governance and lack of finance to meet the huge investment necessity as the main challenges for the deployment of solar, wind and hydro energy in Sub-Sahara African country. In [26], Gezahegn et al. evaluated the prominence of institutional capacity on the dissemination of renewable energy in Ethiopia. In Ref. [27], proper policies on solar energy development, financial encouragement, and technical investigation presented as the most prominent factors that ensure the rapid development of solar power in developing country. In [28], Sindhu et al. pointed lack of suitable government policies and institutional problems emerged as the most influential obstacles for the development of solar power in the Indian rural area. In [29], Labordena et al. identified political instability, weak institutions or corruption as serious problems for a concentrating solar thermal power expansion in Sub-Saharan Africa. In [30], Zhao et al. explored the intermittence nature of power generation by renewable distribute power generation like solar power as one main barriers for its development in China. Berger T [31] presented that lack of intense and sensitive training for users were found to have contributed to failure of solar power system in Ethiopia. In Ref. [32], economic or capital cost is considered as a barrier for the implementation off-grid solar PV systems for developing areas.

In the aforementioned works, valuable analysis into barriers (factors) hindering the growth of solar power system in different countries of the world is addressed. However, few of preceding investigations have tried to examine the interrelationships among these barriers. To the author's knowledge, so far, there's no comprehensive investigation in Ethiopia as well to other neighboring sub-Saharan African country on the analysis of the interactive relationships among the barriers for solar power development. There is also lack of study on prioritizing each barrier as Ethiopian context. Therefore, this study aims to fill this gap by providing a combined ISM and MICMAC method to systematically examine the interrelationship between the descriptive barriers that affect the dispersion of solar powers system in Ethiopia. Since solar-based energy resource is the largest asset in Ethiopia and a detail study of interactions among the barriers influencing the expansion of solar energy in Ethiopia will be used as a helpful database for the other evolving economies.

The main contributions of this study are summarized as follow:

- Identifies the main barriers that influence the development of solar energy in Ethiopia.
- Investigate the appropriate interrelationship among the recognized barriers using ISM and MICMAC technique.
- Develop a judgment structure for articulating strategies using the attained results.
- Serves as a database for the neighboring and other country researchers, to use it as literature for customizing into their country.

The next section of the paper is organized as follows: Methodology of the study is presented in Section 2. Barriers of solar energy growth in Ethiopia have been introduced in Section 3. The analysis of ISM technique to decide levels of recognized barriers are provided in Section 4. MICMAC analysis is explored in Section 5. Discussions of outcomes and recommended ideas to alleviate intensity of barriers are described in Section 6. Finally, conclusions from this investigation are summarized in Section 7.

2 Methodology

As it is tried to explain in the above section, the objective of this research is to identify and analyze the contextual inter-relationships among the barriers affecting the development of solar power in Ethiopia. Comprehensive literature review and collecting different expert's opinion have been done to identify the barriers. To examine the interaction among the recognized barriers, ISM technique is performed. Finally, MICMAC analysis is conducted for further classification of each barrier according to their degree of influence.

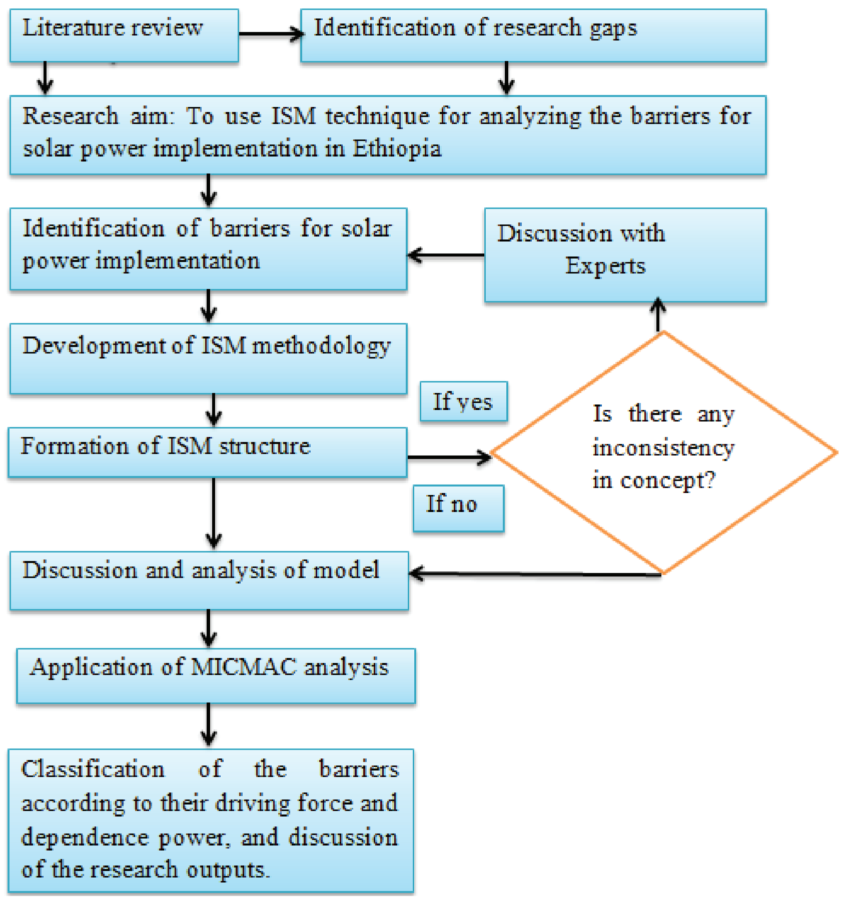

Figure 2 Research procedure and methodology.

The research process is outlined in Figure 2 and the detail analysis of the research process (concept) is given in subsequent sections.

3 Barriers Identification for Solar Power Development

As stated in the introduction section of this paper, it is obvious that the present share of solar power in power generation mix in Ethiopia is not significant due to many barriers in its growing pathway. These barriers can also affect the plan of the government on the realization of universal electricity access by 2025 in the country. The barriers of solar power expansion could be contextual and changed with time, and differ from country to country [33, 34]. Therefore, identifying these barriers specifically in situation to Ethiopia is vital.

In order to distinguish the barriers, extensive review of literature and collecting experts views were carried out. Several databases such as, websites, academics research papers, and numerous reputed journals has been reviewed. Due to inadequate literatures in Ethiopian energy context, selected literatures from developing and developed countries are considered. We assumed similar situation for Ethiopia also. Then discussion with different professionals involved in solar energy industry in Ethiopia was conducted. In this study, seventeen experts from academics, energy authority office, solar vender, industries, and Ethiopian investment commission having a sound knowledge and understanding of solar energy have been accessed to evaluate the importance and the interrelationships between the barriers, using an interview protocol. Based on exhaustive reviewed literature and experts opinions, fifteen (15) relevant barriers have been identified, and described as follows.

3.1 Necessity of High Capital Price (B_1)

Even though the total installation expense of solar PV is falling in each year, a gigantic cost of solar PV power is key barrier to the development of solar PV supply option in developing countries [35]. This high cost is mainly due the deficiency of local manufacturing of this PV technologies, and money developing countries including Ethiopia are reliant on importing the solar PV [36]. Because of this and other additional constraints, adoption of solar energy technologies are still not matured in developing countries compared to other traditional power sources [37]. The total investment cost of solar PV is expected to fall enormously for the next decade throughout the world [38]. Likewise, reduction of price in the case of the other auxiliary components like battery and convertor is also essential. Because, during the past decade storage and converter does not shows significant cost reduction globally as much like PV module as indicated in Table 1.

3.2 Extended Payback Time (B_2)

Because of high initial cost and lower efficiency of solar PV panels, the payback time of solar energy is longer. Even though the prices of solar technologies have come down in the current, however still, the COE of solar power system would be greater than the of COE of conventional grid power

Table 1 The existing and forecasted average capital cost of solar PV and auxiliary components [38–41]

Average Capital Cost	Unit	Years 2021	2030	2050
Solar PV	\$/kW	1050	589	320
Battery (lithium-ion type)	\$/kWh	205	184	150
Inverter	\$/kW	112	92	68

sources in Ethiopia [42]. Furthermore, estimated payback period depends on the location and positioning of solar system. For the locations and positions with more incident sunshine, payback period could be greatly shorter [43].

3.3 Low Efficiency (B_3)

Compared to other conventional energy technologies, efficiency of solar power equipment is less, and according to the investigation conducted in India [44], and in some other developing country [8, 45], efficiency of solar PV is considered as one factor for the less dispersion of solar power system. The existing commercially accessible solar panels efficiency is found in the range of 12–21% [6, 46]. The entire absorbed insolation by cells is not transformed into usable electric supply system. The efficiency of solar panel is affected by various factors for instance, temperature variation, radiation intensity, dirt, voltage drop in connecting wires, geographic position of PV modules and shading by building or tree [47, 48]. Additionally, auxiliary components mentioned in Section 3.2 also decreases the efficiency of solar panel [49]. Therefore, for proper adoption of PV technology, it is necessary to advance the panel efficiency, and development of effective auxiliary components.

3.4 The Issue of Reliability (B_4)

The reliability of solar power technology can be defined as the capability of a system to produce energy per designed size through the life of plant [50]. For solar PV system, the inverter is taken as the leading cause of energy losses [28, 51]. Due to dynamically disruptions in the grid system, and other related problems to integrations, inverter failure is a high frequency event [52]. Furthermore, the other reliability concern is to rise the life of panels [50]. In fact, the panel available in the current market is reliable (in terms of life span), however for additional enhancements, advanced studies and creating good interactions with different manufacturers are needed.

3.5 Storage Device Requirement of (B_5)

Naturally solar power is irregular and it is accessible only in daytime [53]. To get continuous and uninterrupted power supply, this power system is required to be integrated either to battery system or with other power supply system [54]. Manufacturing of storage devices needs a large amount of various minerals.

Its production process produces a huge amount of inorganic dust and fumes which affects the environment and human health [43, 55]. So, by deploying extensive research in the battery technology, robust storage devices are desired in the future to store the power.

3.6 Unavailability of Solar Radiation Data (B_6)

For developing solar power projects in any country, it is essential to get precise radiation data. However, for various developing countries including Ethiopia, there is no properly recorded irradiation data. What commonly accessible is sunshine duration data [42, 56]. Improper solar radiation data for system development may cause inaccurate economic analysis result of the system like decremental or incremental of COE of the system [57]. Different investigations (e.g, [8, 43, 58, 59, 61, 62] examined that lack of proper measured solar radiation data is the major barrier for solar power development in Algeria, Chile, Ethiopia and India. So, it is important to develop updated solar irradiance collector tools and the country should establish its own radiation measurement centers across the country [60].

3.7 Environmental Effects (B_7)

Compared to conventional energy sources, solar power is pure and abundant energy source. To attract peoples towards solar technology it is essential to analyze the environmental advantages attained by this useful energy sources, but this is missed especially in developing country [15, 61]. Whereas considering other aspects, in the process of solar panel manufacturing, emission of large metal happen, that may causes environmental pollutions [62, 63].

3.8 Dust Issues (B_8)

Solar PV panels are exposed to outdoor surroundings and dust and other dirt residue is a key concern for solar power system. Dust deposition on PV modules block the light pathway of the PV cell and results reduction of power generation efficiency [47, 64]. For irradiation of 310 W/m^2, the power output of solar panel deduced by 60%–70% due to dust effect [65].

3.9 Absence of Local Services and Infrastructures (B_9)

To enhance the contribution of solar energy in the Ethiopian energy sector throughout the country, local services and infrastructure plays the key role and identified as a main barrier. It includes land accessibility and procurement difficulties, transmission and clearing services [66, 67]. The implementation of solar projects needs extra infrastructures such as panel support structure, connection roads, and other local infrastructure. Land acquisition is the most important factor and it is challenging process for local and external investors of solar PV developers [68].

3.10 Lack of Financing Mechanism (B_{10})

Solar power technologies are commonly classified as high initial investments and lower operational costs of power plants compared with fossil fuel plants [69]. Due to this reason, solar power developers and consumers have concern in attaining finance by rates as small as might be accessible for conventional power supplies [27, 70]. Furthermore, for reliable and efficient photovoltaic power plant, storage device system is integrated, which needs ample of capitals for installations [54, 71].

3.11 Reluctance of People to Solar Technology (B_{11})

Poor people and rural societies of most developing country lack consciousness about the benefits of utilizing solar power in everyday life [17, 72]. In addition, they don't know about the positive environmental influences of using this renewable power supplies [73]. Consumers are hesitant to accept new technologies by expecting further complexity [74].

3.12 Market Uncertainties (B_{12})

This may comprise lack of involvement by the community in solar technology dispersion. In Ethiopia, even though the concerned stockholder is allowing the solar products to come in the country through tax free to motivate the clean energy growth, the capacity of the solar business center is not sufficient [72]. Therefore, it is important to strengthen public-private partnership to play the main role in the expansion of solar power in several energy intensive places.

3.13 Shortage of Skillful Human Resource and Training Institutions (B_{13})

Lack of proper training institutions, operation and maintenance skilled staff, sales and service agents, research conducting person, can hinder the entire quality of solar supply system [75, 76]. Since solar power plays the major role for the transition of low carbon economy; highly knowledgeable experts with enough experience for implementation of solar technologies with storage device are required [31]. The training institutions will play the main role to get this skilled manpower in the area. However, in Ethiopia, enough persons are not qualified by solar technology and the training institutions are little [72, 77]. So, it is essential to prepare a subject curricula in every academic organizations of the country to fulfill and to get the required skilled human resources.

3.14 Lack of Innovative Applied Research and Development Work (B_{14})

In most part of the globe, the accessibility of solar power is ample and is free naturally, however converting it toward useful form with the help of solar technology is still costly [78]. Convertor and storages connected to solar panel plays a vital role to provide the required regulated power, and during the past decade this auxiliary component does not shows significant cost change compared with solar panel [39]. To increase efficiency of solar PV and to produce low-cost auxiliary devices, innovative research activity plays a major role [27]. Based on various literatures and conversation with the professionals, currently lack of applied investigation and development work in the field of solar power is considered as a barrier for solar energy implementation in Ethiopia. Low investment in research and development is one of the main causes. Keeping in view of this, the concerned stakeholder should make a comprehensive research and development guidelines by arranging appropriate incentives.

3.15 Lack of Adequate Government Polices (B_{15})

Proper policy plays a key role in exciting and promoting clean technologies [79]. Many government policies deficit clearness in strategies, long-term development policy, and proper outline for the growth of solar technologies [80, 81]. Furthermore, in different developing countries, shortage of implementation of the outlined policies also happens [20, 82, 83]. Ethiopia is one of such countries, and there is a limitation on government policies and regulatory for solar energy development. Still the country has not yet finished approval of feed-in tariff (FIT) rule for solar power production. In this manner, it is difficult to achieve the plan of the country on the attainment of universal electricity access. It is essential to review the solar power policies and to follow those who implement the framed policies.

4 ISM Technique for Finding Levels of Barriers

ISM is a commonly used methodology that clearly identifies the interactions between different influencing barriers, and ISM is also applied in this research to examine the complicated relations between the selected barriers for solar power implementation. The conceptual features of ISM method was pioneered by Warfield [84]. The basic characteristics of ISM made it appropriate to use it is, it uses practical skill and perception of professionals to analyze a difficult problem into simpler by constructing various subsystems and building a multilevel structural model [28, 85]. For structuring a complex problem, the composite of three representing languages such as digraph, word and discrete mathematics was applied in ISM analysis. The general steps followed in developing ISM structure are given as follows [86, 87]:

1. Identification of factors should investigated. In this study, barriers for implementation of solar energy in Ethiopia are recognized as factors. The factors are denoted as $B = \{B_1, B_2, B_3 \ldots B_n\}$.
2. Structural self-interaction matrix (SSIM) is developed by conducting comparison among the factors pairwise.
3. Primary reachability matrix is established from SSIM by changing the letter symbols with binary numbers. Then after final reachability matrix is developed using transitivity concept i.e. if L links with M which is linked with N then, absolutely L and N has certain relationship.
4. In this step level subdividing are performed from developed matrix.
5. The representative graph is obtained.
6. Finally, ISM model is prepared.

4.1 Forming Structural Self-interaction Matrix (SSIM)

Various literatures and expert's view are used to recognize the relevant correlation between the barriers in development of solar power in Ethiopia. Experts from academics, electric power generation and distribution office, concerned stakeholder office for solar energy, solar PV Vendor and industries were

Table 2 SSIM for barriers

S.No.	Barriers	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	B_1	A	A	A	A	V	A	A	O	A	A	A	A	O	V	
2	B_2	A	A	A	A	V	A	A	A	A	A	A	A	A		
3	B_3	A	A	A	O	O	O	O	X	O	A	A	A			
4	B_4	A	A	A	A	V	O	O	O	V	A	X				
5	B_5	A	A	O	A	V	A	O	O	V	O					
6	B_6	A	X	A	O	O	O	A	O	O						
7	B_7	A	A	A	O	A	O	A	A							
8	B_8	A	A	A	O	V	O	A								
9	B_9	A	O	V	X	V	V									
10	B_{10}	A	X	X	A	V										
11	B_{11}	A	A	A	A											
12	B_{12}	A	O	A												
13	B_{13}	A	X													
14	B_{14}	A														
15	B_{15}															

accessed to assess the interactions between the 15 barriers. The following 4 symbols were utilized for developing SSIM to indicate the way of relationship between 2 barriers 'i' and 'j'.

V. barrier 'i' supports in achieving barrier 'j'
A. barrier 'j' supports in achieving barrier 'i'
X. barrier 'i' and 'j' supports in achieving each other
O. barrier 'i' and 'j' indicates no connection

In Table 2 the developed SSIM were demonstrated. It is developed on the contextual correlations between the selected barriers. Barrier 1 leads barrier 2, thus designation 'V' was utilized in cell (1, 2); barrier 4 leads barrier 1, thus designation 'A' was utilized in cell (1, 4); barrier 3 and 8 lead within each other, thus designation 'X' was utilized in cell (3, 8); barrier 1 and 8 are not correlated within each other, thus designation 'O' was utilized in cell (1, 8) and in the same way all the cells are filled.

4.2 Establishment of Reachability Matrix

SSIM attained in the above subsection is changed into initial reachability matrix in the form of, binary matrix, by replacing V, A, X, O via 1 or 0 utilizing the following rules [43, 86]:

- Put 'one (1)' in (i, j) entry and 'zero (0)' in (j, i) entry, where 'V' presents in the SSIM.

Table 3 Initial reachability matrix for barriers

S.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
3	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
4	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0
5	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0
6	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0
7	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
8	0	1	1	0	0	0	1	1	0	0	1	0	0	0	0
9	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0
10	1	1	0	0	1	0	0	0	0	1	1	0	1	1	0
11	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
12	1	1	0	1	1	0	0	0	1	1	1	1	0	0	0
13	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0
14	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

- Put 'zero (0)' in (i, j) entry and 'one (1)' in (j, i) entry, where 'A' presents in the SSIM.
- Put 'one (1)' in (i, j) and (j, i) entries, where 'X' presents in the SSIM.
- Put 'zero (0)' in (i, j) and (j, i) entries, where 'O' presents in the SSIM.

The initial reachability matrix obtained for the barriers in the development of solar supply in Ethiopia are shown in Table 3.

Table 4 portrays the obtained final reachability matrix by considering the of transitivity ideas. The marked * symbols in the entry shows transitivity. Lastly, the driving and dependence power were introduced.

4.3 Partitioning the Levels

To get the prominence level of the considered barriers, level partitioning could be conducted. The reachability and antecedent set is reached from final reachability matrix.

Reachability set contains the sets of barrier affected by it and the factors itself. In the antecedent set, the sets of barriers that affect it and the factor itself are taken. Now the intersection of these set is applied for every barrier to determine the level. In the ISM model, level one is designated to the factor that first achieves similar reachability and intersection. For the current case, barriers (factors) 1, 2, 7 and 11 were allocated to level 1 as indicated in the

Table 4 Final reachability matrix for barriers

S.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Driving Power
1	1	1	0	0	0	0	1^*	0	0	0	1	0	0	0	0	4
2	1^*	1	0	0	0	0	1^*	0	0	0	1	0	0	0	0	4
3	1^*	1	1	0	0	0	1^*	1	0	0	1^*	0	0	0	0	6
4	1	1	1	1	1	0	1	1^*	0	0	1	0	0	0	0	8
5	1	1	1	1	1	0	1	1^*	0	0	1	0	0	0	0	8
6	1	1	1	1	1^*	1	1^*	1^*	0	0	1^*	0	1^*	1	0	11
7	1	1	0	0	0	0	1	0	0	0	1^*	0	0	0	0	4
8	1^*	1	1	0	0	0	1	1	0	0	1	0	0	0	0	6
9	1	1	1^*	1^*	1^*	1	1	1	1	1	1	1	1	0	0	13
10	1	1	1^*	1^*	1	1^*	1^*	1^*	1^*	1	1	1^*	1	1	0	14
11	1^*	1^*	0	0	0	0	1	0	0	0	1	0	0	0	0	4
12	1	1	1^*	1	1	1^*	1^*	1^*	1	1	1	1	1^*	1^*	0	14
13	1	1	1	1	1^*	1	1	1	1^*	1	1	1	1	1	0	14
14	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	12
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Dependency Power	15	15	11	9	9	7	15	11	5	6	15	5	7	6	1	137/137

Table 5 First step iteration

Barriers	Reachability Set	Antecedent Set	Intersection	Level
B_1	1,2,7,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1,2,7,11	1st
B_2	1,2,7,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1,2,7,11	1st
B_3	1,2,3,7,8,11	3,4,5,6,8,9,10,12,13,14,15	3,8	
B_4	1,2,3,4,5,7,8,11	4,5,6,9,10,12,13,14,15	4,5	
B_5	1,2,3,4,5,7,8,11	4,5,6,9,10,12,13,14,15	4,5	
B_6	1,2,3,4,5,6,7,8,11,13,14	6,9,10,12,13,14,15	6,13,14	
B_7	1,2,7,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1,2,7,11	1st
B_8	1,2,3,7,8,11	3,4,5,6,8,9,10,12,13,14,15	3,8	
B_9	1,2,3,4,5,6,7,8,9,10,11,12,13	9,10,12,13,15	9,10,12,13	
B_{10}	1,2,3,4,5,6,7,8,9,10,11,12,13,14	9,10,12,13,14,15	9,10,12,13,14	
B_{11}	1,2,7,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1,2,7,11	1st
B_{12}	1,2,3,4,5,6,7,8,9,10,11,12,13,14	9,10,12,13,15	9,10,12,13	
B_{13}	1,2,3,4,5,6,7,8,9,10,11,12,13,14	6,9,10,12,13,14,15	6,9,10,12,13,14	
B_{14}	1,2,3,4,5,6,7,8,10,11,13,14	6,10,12,13,14,15	6,10,13,14	
B_{15}	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	15	15	

Table 5. Then level one (1) is discarded for the succeeding iteration to realize additional levels. The second level of iteration to partition the levels of barrier are shown in Table 6. The iterative process is continued until the level of all barriers is achieved, and the summery of the attained level is illustrated in Table 9.

Table 6 Second step iteration

Barriers	Reachability Set	Antecedent Set	Intersection	Level
B_3	3,8	3,4,5,6,8,9,10,12,13,14,15	3,8	2nd
B_4	3,4,5,8	4,5,6,9,10,12,13,14,15	4,5	
B_5	3,4,5,8	4,5,6,9,10,12,13,14,15	4,5	
B_6	3,4,5,6,8,13,14	6,9,10,12,13,14,15	6,13,14	
B_8	3,8	3,4,5,6,8,9,10,12,13,14,15	3,8	2nd
B_9	3,4,5,6,8,9,10,12,13	9,10,12,13,15	9,10,12,13	
B_{10}	3,4,5,6, 8,9,10,12,13,14	9,10,12,13,14,15	9,10,12,13,14	
B_{12}	3,4,5,6,8,9,10, 12,13,14	9,10,12,13,15	9,10,12,13	
B_{13}	3,4,5,6,8,9,10,12,13,14	6,9,10,12,13,14,15	6,9,10,12,13,14	
B_{14}	3,4,5,6,8,10,13,14	6,10,12,13,14,15	6,10,13,14	
B_{15}	3,4,5,6,8,9,10,12,13,14,15	15	15	

Table 7 Third step iteration

Barriers	Reachability Set	Antecedent Set	Intersection	Level
B_4	4,5	4,5,6,9,10,12,13,14,15	4,5	3rd
B_5	4,5	4,5,6,9,10,12,13,14,15	4,5	3rd
B_6	4,5,6,13,14	6,9,10,12,13,14,15	6,13,14	
B_9	4,5,6,9,10,12,13	9,10,12,13,15	9,10,12,13	
B_{10}	4,5,6,9,10,12,13,14	9,10,12,13,14,15	9,10,12,13,14	
B_{12}	4,5,6,9,10, 12,13,14	9,10,12,13,15	9,10,12,13	
B_{13}	4,5,6,9,10,12,13,14	6,9,10,12,13,14,15	6,9,10,12,13,14	
B_{14}	4,5,6,10,13,14	6,10,12,13,14,15	6,10,13,14	
B_{15}	4,5,6,9,10,12,13,14,15	15	15	

Table 8 Fourth step iteration

Barriers	Reachability Set	Antecedent Set	Intersection	Level
B_6	6,13,14	6,9,10,12,13,14,15	6,13,14	4th
B_9	6,9,10,12,13	9,10,12,13,15	9,10,12,13	
B_{10}	6,9,10,12,13,14	9,10,12,13,14,15	9,10,12,13,14	
B_{12}	6,9,10, 12,13,14	9,10,12,13,15	9,10,12,13	
B_{13}	6,9,10,12,13,14	6,9,10,12,13,14,15	6,9,10,12,13,14	
B_{14}	6,10,13,14	6,10,12,13,14,15	6,10,13,14	
B_{15}	6,9,10,12,13,14,15	15	15	

In this investigation, six levels of barriers in growth of solar supply in Ethiopia were attained. necessity of high capital price (B_{01}), extended pay-back time (B_{02}), the concern of environment (B_{07}) and hesitancy of peoples to solar technologies (B_{11}), were found out as upmost barrier, and shortage of adequate government policies (B_{15}) have been appeared as bottom most barrier.

Table 9 The whole levels of barriers

S.No	Level No.	Barrier to Develop Solar Power
1	1st	B_1, B_2,B_7,B_{11}
2	2nd	B_3,B_8
3	3rd	B_4,B_5
4	4th	B_6
5	5th	B_9,B_{10},B_{12},B_{13},B_{14}
6	6th	B_{15}

4.4 ISM Model Development

Once all levels are obtained, development of the graphical structural, which concludes the final ISM model would be conducted as illustrated in Figure 3. Barriers necessity of high capital price (B01), extended payback time (B02), the concern of environment (B07) and hesitancy of peoples to solar technologies (B11) found at the uppermost of the ISM hierarchy configuration as level 1, showing they are extremely dependent. Lack of suitable government policy (B_{15}) has found at the foot level of the model, which indicates that it is prominently driving barrier and it doesn't depend on other factors. Barriers that lies between bottommost and top levels are lower efficiency (B_3), the issues of dust (B_8), the case of reliability (B_4), necessity of storages (B_5), unavailability of proper solar radiation data (B_6), absence of local services and infrastructure (B_9), deficiency of financing issues (B_{10}), market uncertainties (B_{12}), lack of skillful human and training institutions (B13), and shortage of advanced applied research and development work (B14).

5 Barrier Classification

Further arrangements of factors are conducted based on driving and dependence power using MICMAC analysis. The driving power, DR_i, and dependence power, DE_j, can be analyzed by the following formulae [88, 89]:

$$DR_i = \sum_{j=1}^{n} a_{ij} (i = 1, 2, 3 \ldots n) \tag{1}$$

$$DE_j = \sum_{i=1}^{n} a_{ji} (j = 1, 2, 3 \ldots n) \tag{2}$$

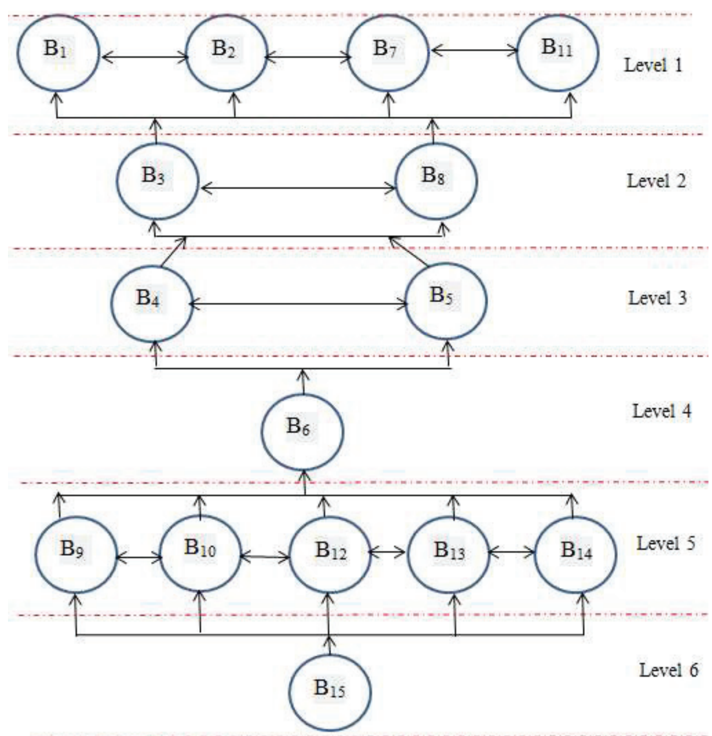

Figure 3 ISM model of barriers.

Based on Equations (1) and (2), the driving power of DR_i refers to the entire number of barriers affected by it, which is obtained by summating the whole entry values of row in the reachability matrix. On the other hand, the dependence power of DE_j mentions to the overall number of barriers hindering this particular barrier, that can be analyzed by summating the value all entry of column in the reachability matrix.

By utilizing the dependence power as the abscissa and driving force as the ordinate, the dependence/driving quadrants of the affecting barriers can be sketched with the representation each barriers in the coordinate system as revealed in Figure 4. The barriers are divided into four groups, as follows [90, 91]:

Group 1: Autonomous barriers; this group of factors has weak driving and dependence power. They are comparatively detached from the system. They have little links within the factors. In our study, none of the barriers appeared as autonomous.

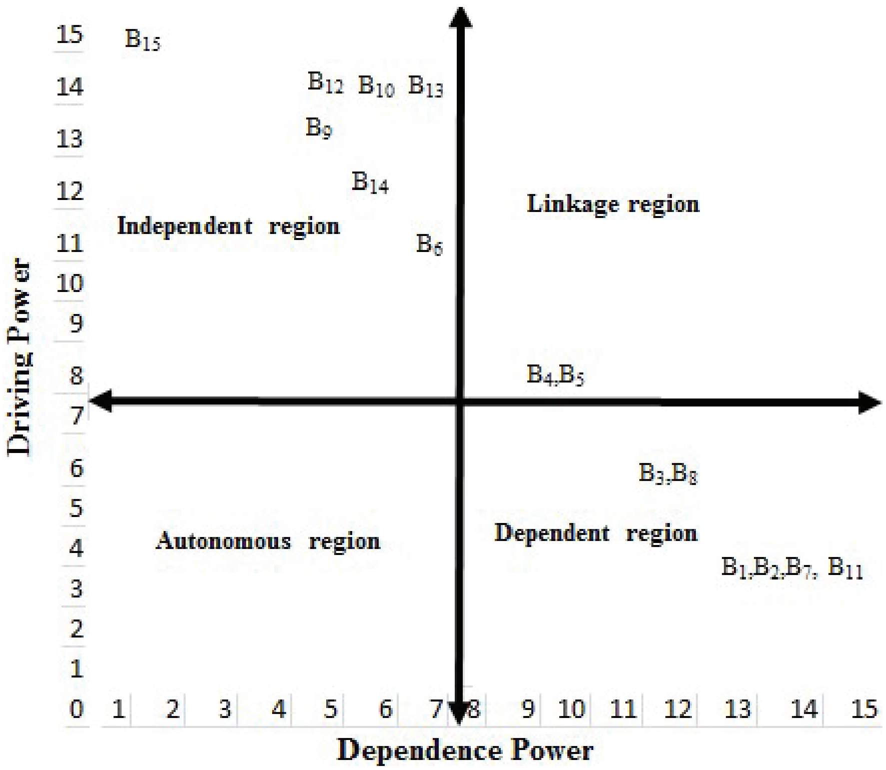

Figure 4 Driving versus dependence power utilizing MICMAC examination.

Group 2: Dependent barriers; this group of factors has a weak driving power and strong dependence force. In our investigation, six barriers i.e. necessity of high capital price, extended payback time, lower efficiency, the concern of environment, the issues of dust and hesitancy of peoples to solar technologies (barriers 1, 2, 3, 7,8 and 11) are laid in this cluster. Group 3: Linkage barriers; this group of factors has a strong driving power as well as strong dependence force. Barrier named reliability issues and requirement of storage device (4 and 5) are lying in this range Group 4: Independent barriers: this group of factors has a strong driving power but weak dependence power. In this group there are seven barriers i.e. inaccessibility of proper irradiation data, absence of local facilities and infrastructures, deficiency of financing mechanism, market uncertainties, absence of skillful human resource and training institutes, shortage of advanced applied investigation and development work, and lack of adequate government polices (barriers 6, 9,10,12,13,14 and 15) respectively.

6 Discussion

Electric energy is an important sector for economic enhancement of every country and accordingly, expansion of the energy sector is indirectly associated to the development of a country. Ethiopia is well donated with various renewable energy resources, and currently Ethiopia is trying to explore all clean power sources in order to confront the challenges of its economic development, carbon emissions, and country's 2025 universal electricity access plan [3, 5].

Even though the country is trying to explore all clean energy sources, dispersion of solar PV technologies in the country is still far from satisfactory because of different barriers be present that influence the implementation of solar energy. In this study, barriers have been identified and correlation among these factors has been explored using ISM method. To validate ISM model, MICMAC exploration were applied based on dependence power and driving force of the identified factors. Figure 3 demonstrates the interactions between the barriers influencing the expansion of solar energy, and Figure 4 validates the dissemination of these barriers from the dependence and driving power viewpoint. From the two figures, it can be observed that driving powers look at the foot two ranks of the ISM configuration. Mainly, from the 7 (seven) driving powers, B_{15} (lack of adequate government strategy) ought be given top precedence as this barrier was found at the lowermost level of ISM order configuration and has comparatively the biggest driving power. This recommends that government policy (B_{15}) is the foremost important barriers, and act as the main source of representative barriers influencing the sustainable growth of solar energy in Ethiopia.

6.1 Recommended Actions to Alleviate Barriers

To get diversified and secure energy in the country, it is important to overcome barriers of solar power implementation. Based on this study analysis, following are some suggested solutions for reducing or eliminating barriers:

- Framing resilient government strategies recommended through outputs of ISM structure is very important. Providing flexible policy models by policymakers might inspire speculators for solar developments in the societies. Specially, the concerned stakeholder should implement feed–in tariff technology throughout the country. Since feed-in tariff system could have tremendous impact because it can simply pull in private divisions, and this can be especially vital to countries like Ethiopia who have populations alive in dispersed situations.

- Government officials and concerned stakeholder have to spend sufficient period and reserves to improve awareness in solar power technologies. Popularization of the regulations is needed, and the people might realize it in simpler way.
- Ethiopian government ought to emphasize on foundation of adequate teaching institutions to guarantee the accessibility of technically sound people for solar power dispersion.
- The existing solar panel installed in Ethiopia is primarily reliant on the external producer, which is not fruitful for development and improvement of the solar marketplace in the country. To ease this, it is essential to increase production capability of PV panel and its related modules inside the country.
- Government must ensure fundamental infrastructural services to distributer as a main necessity for motivating solar advancement in a specific area.
- The government and other upper level body included in the decision sector might use this study to advance its awareness with the factors for the acceleration of solar energy expansion in the country.

7 Conclusions

Solar energy is recognized as a favorable option for lessening fossil oil utilization. The development of solar energy is a challenging scheme that is affected by enormous number of barriers. In this regard, fifteen barriers are acknowledged and evaluated in Ethiopian context as a hindrance for solar power development. The ISM method has been implemented to generate the structural configuration and to find the dependence and driving powers of barriers. For the confirmation of the model, MICMAC examination is conducted. The barriers for development of solar supply in Ethiopian context are iterated in 6 (six) ranks.

High capital prices, extended payback time, the concern of environment and hesitancy of peoples to solar technologies have occurred at the topmost level of ISM configuration. These top level barriers were found in the dependent quadrant. Elimination of these factors mainly depends on the eradication of other factors. Lack of appropriate government policy barrier appeared at the bottom rank of the model. This barrier is known as driver barrier and it is influential barrier. Elimination of this barrier can support in removal of other barriers. In current ISM model, none of the barriers appears in the autonomous region. The case of reliability and necessity of storages are act linkage barriers which is an unsteady barriers. If some activity is conducted on these barriers, it will affect other factors and itself moreover.

To generalize, the finding of this research provides an essential course of measures for different academics, manufacturers, policy makers and solar PV vendors in local as well international levels; and will help the solar energy technology regulators, experts, and researchers in their future researches.

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