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What Stops to Switch on to Solar Energy? An Empirical Evidence from Pakistan

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Abstract
This is an exploratory and qualitative study based on a survey. The study aims to generate a list of factors hindering switching to solar energy systems. The study design comprises the literature review, data analysis and discussion. The population under study includes stakeholders of solar energy systems, e.g., solar penal producers, importers, sellers, marketers, buyers/consumers, regulators, etc. Twenty-one samples are drawn from within the stakeholders, constituting a non-probability purposive sample of experts. The data are collected using a matrix-type questionnaire from experts. To perform analysis on data, the classical technique of Interpretive Structural Modeling (ISM) combined with Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) is used. Findings of ISM modeling show that limited production and uncertainty about after sale service fall at *Level I,* in contrast, lack of expertise and lack of social awareness fall at *Level V & VI* (respectively) of the model. All other barriers lye in middle on the continuum of bottom-to-top. It is worth mentioning that the barriers contained at *Level I* are the least important and those held at *Level V & VI* are the most important ones. Findings of MICMAC show that barriers, namely limited production and uncertainty about after sale service, fall in the *independent cluster.* In contrast, barriers, namely weak infrastructure structure, non-availability of feed-in tariff (fit) system, limited production and uncertainty about after sale service, fall in the *dependent cluster.* All the other barriers fall in the *linkage cluster.* This is an original valuable study based on real-time data collected from stakeholders that contributes new information about inter-relationships of barriers about the phenomenon under study. The study has various implications for the stakeholders, i.e. solar penal producers, wholesalers, retailers, importers, marketers, regulators, buyers, society and economy, etc.
Keywords: Solar Energy Systems, Solar Panels, Renewable Resources, ISM, SmartISM, MICMAC

1. Introduction

In this era of machines and mass production, a massive amount of energy in different forms is required. Energy science researchers are always on tows to support industrial and domestic needs. Coal-based energy systems are one of the oldest resources of energy. Energy currently obtained from traditional sources like a furnace, wind mills, and nuclear power plants are i) expensive, ii) insufficient, iii) pollutive, and iv) unfriendly to our environment. Currently, the close alternative seems to be solar sources. Solar energy is a form of energy produced by the sun. Sun is the major source of all types of energy. Primary forms of solar energy are heat and sunlight absorbed by our environment and later converted into secondary forms of energy, i.e., wind energy, thermal energy, biomass energy, etc., that are usable in many sectors (Patel, Darji, & Qureshi, 2017; Sindhu et al. 2016). Homes, industries, and businesses use different solar technologies to bring variety to their energy sources. Solar energy is a source of energy that can be renewed (Baharoon, Rahman, & Fadhl, 2016). A massive amount of energy is provided by the sun that can be used to meet the needs of the whole of the world. Unlike other energy resources, solar energy is a clean energy source as it does not produce harmful emissions and is environment friendly (Păceşilă et al., 2015). It is advantageous in minimizing greenhouse gases and increasing levels of carbon footprint. Pakistan is a developing country, and it relies mainly on those resources of power generation which are not renewable. Natural resources like oil, liquefied natural gas and coal are being deployed to fulfill the country's energy needs. Pakistan is running out of energy resources, while, on the other hand, the energy needs are increasing and not adequately fulfilled. Pakistan is economically under pressure, and there is an intense need to switch to a cheap and environment friendly energy source. The climate of Pakistan is perfect for producing solar power but it still relies on fossil fuels (Farooq & Shakoor, 2013). It is a time when solar power production is much needed in Pakistan, but so far, Pakistan could not switch to solar energy. There is an array of barriers that hinder desired switching. It is a call of the day to investigate the factors that hinder to invert of solar, and it is also vital to examine how they are related to each other and with other systems. Therefore, this study focuses on the phenomenon. The scope of the study is to find the factors that are the barriers to switching to solar energy.

To be more specific, the study's objectives are: i) to identify the barriers to adopting solar power, ii) to construct a demonstrative model, iii) to make discussions on the model, and iv) to put forward the practical implications of the study. To achieve the objectives, different methodologies have been considered. Among a wide range and variety of options available, it is found that the ISM is the most suitable research technique for the issue under study because it incorporates explicit and distinct models to express the complex and knotty problems as well as rank the variables and generate the interrelationships among those variables to provide understanding about their impact in the overall system (Abbass, et al., 2021; Qazi, et al., 2021; Shaukat, et al., 2021a & b; Niazi, et al., 2020; Niazi, et al., 2021). ISM aids in representing the shattered and broken up knowledge into valuable and workable knowledge (Sushil, 2017; Chidambaranathan et al., 2009; Warfield, 1973; Warfield, 1974; Audi & Ali, 2017; Fu et al., 2022a & b; Javaid, Shoukat, & Niazi, 2022; Qureshi, et al., 2022a & b; Basit, et al., 2021; Ashiq et al., 2023; Audi et al., 2023).

Along with ISM modeling, Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) is used for stratifying and categorizing factors (Godet, 1986; Qureshi, et al., 2022a & b; Shaukat, et al., 2021b; Ali et al., 2022; Ali et al., 2021; Niazi, et al., 2020a; Niazi, et al., 2020b; Niazi, et al., 2020c; Niazi, Qazi, & Basit, 2020; Qazi, et al., 2019; Audi & Ali, 2023). Moreover, MICMAC is used to corroborate the findings of ISM. The rest of the study design comprises the literature review, methodology & layout, data analysis, results, discussion, and conclusion.

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2. Literature Review

It is vital to review contemporary and relevant literature to identify and extract an initial list of factors that discourage users from switching to solar energy systems. Aware of its usefulness, a comprehensive systematic review was performed on renowned publishers, i.e., Emerald, Science Direct, Wiley-Blackwell, JStor, Taylor & Francis, Ebscohost, MDPI, Sage, Hindawi etc. For retrieving to-the-point accurate information regarding the issue under study, keywords such as solar, solar energy issues, barriers in switching to solar energy, problems of solar energy, hindrances in the adoption of solar energy, problems in switching to solar energy, alternate energy sources, renewable energy sources, etc. are entered on google search engine. Through the search, we could generate a depository of 700 plus publications directly/indirectly related to the domain of the study. From the initial list, the most relevant publications are made part of the literature illustrated herein for brevity. Literature about barriers to implementing solar systems was reviewed in different countries' contexts (Ohunakin et al., 2014). Solar energy is the energy emitted by the sun in the form of radiation, 365 days per year. It has been used for drying agricultural products, heating in cold seasons and areas, or ventilation purposes (Gunerhan et al.2008). The solar energy system positively impacts the environment, economy, and society (Păceşilă, 2015). A country's economic and social stability is strongly related to energy availability. The prosperity of any country is also measured by energy composition per capita. Unfortunately, Pakistan is one of the energy-deficient countries where energy consumption per capita was recorded 425kWh for the year 2004–2005 against a world record of 2516kWh (Asif, 2009). In the present scenario, the energy supply is also lagging behind the demand for it in Pakistan. Worldwide economic growth and developments are tied to the availability of energy which also has created upward pressure on the energy demand. Furthermore, the world demand for energy is increasing significantly because of uncontrolled population growth and industrial evolution. It is important to mention here that the population has increased by 2 billion just in one generation, largely contributed by developing countries (Kannan, & Vakeesan, 2016). On the other hand, enough resources are unavailable to cope with increasing demands (Sáez-Martínez et al., 2016). Solar energy systems have proved to be promising sources of energy worldwide. Developing nations like Pakistan have started efforts to capitalize on the benefits of solar energy solutions (Iram et al. (2021). Solar energy heating systems are highly efficient and sustainable (Balta et al. (2011). Solar energy provides a flexible energy source, and assessment of the energy source is the basic step toward its utilization (Ramachandra et al. 2005). The decision to adopt renewable energy is driven by the perceived utility of new technology, the perceived utility of renewable energy, and the perceived benefit of the news source, whereas the perceived expense inhibits it (Baharoon, Rahman, & Fadhl, 2016). There is a need to promote the adoption of renewable energy resources among residential users to capitalize on the constructs of these resources (Zahari et al. (2018). Environmental, performance, and government concerns affect the adoption of solar penal (Kumar et al. 2022). Zulu et al. (2021) asserted that the intention to adopt solar power systems is affected by attitude towards solar energy solutions, subjective norms, perceived benefits, perceived trust, knowledge about solar energy solutions, load-shedding, and social norms.

Table 1: List of barriers in the way of adoption of Solar Energy

Code	Factors	Description	Source
1	Lack of expertise	Lack of expertise in the domain of study hampers people from offering services and hence deters buyers from adopting solar energy systems	(Nandal et al., 2019)
2	Too high startup cost	Too high startup cost deters most Pakistan people from adopting solar energy systems.	(Nandal, et al. 2019; (Ansari, et al. 2013)
3	Lack of social awareness	Lack of social awareness/marketing affects the acceptability of a product	(Nandal et al., 2019)
4	Status quo with traditional sources	People like to work with conventional sources.	(Ansari et al., 2013)
5	Confusing policies for investors	The absence of confusing policies for investors leads to local production/supply of solar penlas.	(Painuly, 2001)
6	Insufficient subsidies/support	Lack of subsidies/support from the government significantly affects promoting a specific sector.	(Painuly, 2001)
7	Unavailability of skilled workers	Lack of skillful workers, viz. designers, operational pre/after-sales service agents, installation personnel, etc., can affect the quality of the overall solar system.	(Nandal et al., 2019)
8	An absence of loans facilities for solar setups	The financing mechanism is not sufficient to promote solar energy systems.	(Ansari et al., 2013)
9	Weak infrastructure structure	Solar panels are mainly imported, and the devaluation of local currency increases the cost of imported items.	(Ansari et al., 2013)
10	Non-availability of feed-in tariff (FiT) system	Non-availability of a feed-in tariff (FIT) policy fails to support producers.	(Painuly, 2001)
11	Limited production	Lacks of demands and production resources limits the production volume	(Patel et al.,2017; Painuly, 2001)
12	Scarcity of authentic information	It increases uncertainty and hence product cost.	(Painuly, 2001)
13	Performance risks	Performance risk affects the intentions of buyers negatively to adopt a solar system	(Kumar et al. 2022; Zulu, et al. 2021)
14	Uncertainty about after-sale service	Consumers unaware of after-sale services hesitate to adopt solar energy systems.	(Kumar et al., 2022)
15	High replacement cost batteries	Expensive batteries required for replacement increases the cost of the overall system.	(Kumar et al., 2022)

In contrast, the perceived behavioral control, risk, and cost are not linked. Roy & Mohapatra (2021) asserted that behavioral intention of solar power system adoption is affected positively by its performance & effort expectancy, social influence, and hedonic. The solar system installation in homes and industries can do wonders per the infographics (Leaman, 2015). The use of solar energy systems is justified through its advantages of suitability to the environment, minimal cost (in the long run), and wide versatility

(Guangul and Chala 2019). Renewable energy sources provide excellent opportunities over conventional sources to mitigate greenhouse gas emissions and alarming global warming (Panwar et al. 2011). Among the available options of renewable energy sources, solar energy is a promising option due to its extensive availability. Solar power has a wide variety of benefits for developing nations e. g. sustaining the lives of millions and protecting the environment (Devabhaktuni et al., 2013). Despite the huge benefits of the solar power system, there seem to exist some barriers that deter consumers from switching completely to the solar system (Baharoon, Rahman, & Fadhl, 2016; Nalan, Murat, & Nuri 2009; Painuly, 2001). An array of barriers that contribute to the issue includes cost effectiveness, technical, marketing, political, social, environmental, and regulatory barriers (Painuly, 2001). Nalan, Murat, & Nuri (2009) asserted that solar energy is a renewable resource for sustainable future development and challenges in moving toward a solar system. It also asserts that solar system adoption was conducted worldwide in different countries with different barriers. Farooq & Shakoor (2013) focused on Paksitan and concluded that emerging countries like Pakistan suffer from serious energy crises. Presently Pakistan is facing a severe shortfall of energy; in fact, it has been facing an energy crisis since its inception in 1947. The shortfall of energy has affected every sector and life of every person in Pakistan. Economic growth has declined due to the energy crisis, which has given rise to other vices like inflation, unemployment, currency devaluation, and other physical & social crimes, i.e., street theft, intolerance, suicides, depression, anxiety, etc. Pakistan is blessed with various renewable energy resources, including sunlight. Painuly (2001) bolstered that using renewable energy resources for economic sustainability and social development is the need of time. Still, the real potential of renewable resources is not even legalized in some countries due to barriers (Kumar et al., 2022). The world's dynamics, i.e., globalization and industrialization, demand the use of renewable energy resources. To meet the energy requirements of the growing population, it is important to utilize natural energy resources appropriately. As a result of the aforementioned review, a list of barriers to switching to solar energy emerged that had been kept in Table 1 with the source.

Table 1 presents the barriers to solar energy adoption, their descriptions, and the sources. The analysis in this study is built on the barriers presented herein.

3. Methodology & Design

The research approach is inductive, qualitative, and survey based on the philosophy of interpretivism. The study design comprises the literature review, data collection, analysis, and discussion. The population under study includes stakeholders of solar energy systems, e.g., solar penal producers, importers, sellers, marketers, buyers/consumers, regulators, etc. A representative sample of twenty-one is drawn from within the stakeholders that constitute a non-probability purposive sample of experts (detailed discussion in forthcoming section). The data are collected using a matrix-type questionnaire from experts. To perform data analysis, the ISM technique combined with Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) is used (Sushil, 2017; Chidambaranathan et al., 2009; Warfield, 1973; Warfield, 1974; Fu et al., 2022a & b; Javaid, Shoukat, & Niazi, 2022; Qureshi, et al., 2022a & b; Basit, et al., 2021; Abbass, et al., 2021; Qazi, et al., 2021; Shaukat, et al., 2021a & b; Niazi, et al., 2020; Niazi, et al., 202;1Qureshi, et al., 2022a & b). The complete study procedure is adopted from Abbass et al. (2021) and we used SmartISM Software for analysis and modeling (Ahmad, & Qahmash, 2021).

The panel of Experts: Where the data concerning the phenomenon is not available, insufficient, not reliable, etc., it is advisable to elicit the same from the mental models of experts. Experts are the people who have sufficient expertise and scientific and practical knowledge of the phenomenon under study. Panels are customarily constituted from within the stakeholders, and the panel size depends on the experts' nature to be included in the panel. For homogeneous experts, the panel size varies from 10-25, whereas that of heterogeneous varies from 8-15 but the optimum size is around 25 experts (Clayton, 1997; Khan & Khan, 2013; Niazi, et al., 2019; Niazi, Qazi, Basit, & Khan, 2019; Niazi, Qazi, & Sandhu, 2019; Niazi, Qazi & Basit, 2019a; Niazi, Qazi & Basit, 2019b; Niazi, Qazi & Basit, 2019c). However, this is to some extent a subjective matter; the size of a panel may vary according to the nature of the study. The ISM study is workable with even fewer experts to five and even more to fifty experts (Javaid et al. 2022; Fu et al. 2022a; Abbass et al., 2022a; Fu, et al., 2022b; Abbass, et al., 2022b; Basit, et al., 2021; Abbass, et al. 2021; Shaukat, et al., 2021a). The data collected from the panel gives depth instead of breadth and outweighs the statistical data sets. For the study and to recruit the experts on the panel, recruitment criteria include; i) every member of the panel should be a minimum university graduate, ii) have a minimum of ten years of relevant experience, iii) have expert theoretical, technical, and scientific knowledge, iv) have some acumen of research and v) is willing to contribute towards the study (Abbass et al. 2022a & b; Basit et al. 2021; Abbass et al. 2021). The size of the panel for this study is twenty-one experts. More than thirty-five people were identified and invited to participate in the study. Of which twenty-five people participated in the study. Since we used a matrix-type questionnaire, a relatively complex form of a questionnaire, some of the questionnaires contained stereotype data and were not usable; therefore, they were excluded from the study. Finally, this study is built on twenty-one valid questionnaires. The panel included three university professors having research publications on solar energy, four managers of large-sized public sector organizations responsible for smooth running and maintenance of solar systems in their organizations, one chief executive officer of a solar penal selling company, one from government officials/regulators, six from solar energy users and six from potential users of solar energy. The experts have been approached thrice; once for factor verification, second for rapport development and data collection, and third for model verification. Most of the experts have come in their office setting. It took us approximately three months to verify, collect and analyze the data. There are different methods for eliciting the data from the experts' minds, e.g., the Delphi method, brainstorming session, RGT, questionnaires of different types etc. We used a matrix-type questionnaire and semi-structured interviews in a one-to-one setting.

4. Analysis, Results, and Discussion

This section presents modeling and classification of barriers to switching to solar energy, where modeling is performed through ISM and classification through MICMAC.

Table 2: Structural Self-Interaction Matrix (SSIM)

Code	Barriers	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Lack of Expertise	LE		V	A	O	V	V	O	O	O	O	V	V	V	V	O
2	Too High Startup Cost	THSC			O	O	V	A	O	O	O	O	V	A	O	O	O
3	Lack of Social Awareness	LSA				O	O	O	V	O	O	O	O	O	O	O	O
4	Status quo with Traditional Sources	STS					A	O	V	A	O	V	V	A	X	O	A
5	Confusing Policies for Investors	CPI						V	O	A	O	O	V	A	O	O	O
6	Insufficient Subsidies/Support	ISS							A	O	V	O	O	V	O	O	A
7	Unavailability of Skilled Workers	USW								V	O	O	V	O	V	V	O
8	Dearth of Loans Facilities for Solar Setups	DLFSS									O	O	V	A	O	V	O
9	Weak Infrastructure Structure	WIS										A	V	A	O	V	O
10	Non-availability of feed-in tariff (FiT) system	NFTS											O	O	O	O	O
11	Limited Production	LP												O	O	O	O
12	Scarcity of Authentic Information	SAI													O	V	V
13	Performance Risks	PR														O	O
14	Uncertainty about After Sale Service	UASS															O
15	High Replacement Cost Batteries	HRCB															

Table 3: Initial Reachability Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0
2	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
3	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0
5	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0
6	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0
7	0	0	0	0	0	1	1	1	0	0	1	0	1	1	0
8	0	0	0	1	1	0	0	1	0	0	1	0	0	1	0
9	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
10	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	0	1	0	1	1	0	0	1	1	0	0	1	0	1	1
13	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
15	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1

Table 4: Final Reachability Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Driving
1	1	1	0	1*	1	1	1*	1*	1*	1*	1	1	1	1	1*	14
2	0	1	0	1*	1	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	13
3	1	1*	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	15
4	0	1*	0	1	1*	1*	1	1*	1*	1	1	1*	1	1*	1*	13
5	0	1*	0	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	13
6	0	1	0	1*	1*	1	1*	1*	1	1*	1*	1	1*	1*	1*	13
7	0	1*	0	1*	1*	1	1	1	1*	1*	1	1*	1	1	1*	13
8	0	1*	0	1	1	1*	1*	1	1*	1*	1	1*	1*	1	1*	13
9	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	3
10	0	0	0	0	0	0	0	0	1	1	1*	0	0	1*	0	4
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
12	0	1	0	1	1	1*	1*	1	1	1*	1*	1	1*	1	1	13
13	0	1*	0	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	13
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
15	0	1*	0	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1	13
Dependence	2	11	1	11	11	11	11	11	13	12	14	11	11	14	11	

4.1. ISM Modelling

ISM modeling is a methodology that proceeds stepwise. The stepwise procedure for this study has been adopted (Abbass et al., 2021). The data collected from the survey method was aggregated through M.S. Excel using "count if" to calculate the mode (i.e.

the most frequent value/symbol for each paired relation). This way, the Structural Self-Interaction Matrix (SSIM) is generated as Table 2.

The SSIM (Tabe 2) is entered into SmartISM Software for analysis and modeling (Ahmad, & Qahmash, 2021). SmartISM Software is a software that runs routines on the data set according to the principles of ISM modeling devised by Warfield (1973) and Attri, Dev, & Sharma (2013). It also generates cross impact matrix multiplication applied to classification popularly known as MICMAC as suggested by Godet (1986). Tables 3-6 and Figures 1-3 are generated from the software and reported accordingly with minor formatting/presentation improvements.

Table 5: Level Partitioning (LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1,	1, 3,	1,	*V*
2	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
3	3,	3,	3,	*VI*
4	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
5	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
6	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
7	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
8	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
9	9,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15,	9,	*II*
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 15,	10,	*III*
11	11,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15,	11,	*I*
12	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
13	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*
14	14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15,	14,	*I*
15	2, 4, 5, 6, 7, 8, 12, 13, 15,	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 15,	2, 4, 5, 6, 7, 8, 12, 13, 15,	*IV*

As a result of partitioning of transitive binary matrix, the levels of the factors are determined as given in Table 5. The barriers are rearranged across the columns and rows according to the levels and a model appeared on diagonal cells (i.e. marked as grey). Driving, dependence, and levels of barriers can also be seen there-against in this Table 6.

Table 6: Conical Matrix (CM)

Variables	11	14	9	10	2	4	5	6	7	8	12	13	15	1	3	Driving	Level
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	*I*
14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	*I*
9	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	*II*
10	1*	1*	1	1	0	0	0	0	0	0	0	0	0	0	0	4	*III*
2	1	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1*	0	0	13	*IV*
4	1	1*	1*	1	1*	1	1*	1*	1	1*	1*	1	1*	0	0	13	*IV*
5	1	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1*	0	0	13	*IV*
6	1*	1*	1	1*	1	1*	1*	1	1*	1*	1	1*	1*	0	0	13	*IV*
7	1	1	1*	1*	1*	1*	1*	1	1	1	1*	1	1*	0	0	13	*IV*
8	1	1	1*	1*	1*	1	1	1*	1*	1	1*	1*	1*	0	0	13	*IV*
12	1*	1	1	1*	1	1	1	1*	1*	1	1	1*	1	0	0	13	*IV*
13	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1*	0	0	13	*IV*
15	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1	0	0	13	*IV*
1	1	1	1*	1*	1	1*	1	1	1*	1*	1	1	1*	1	0	14	*V*
3	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1	1	15	*VI*
Dependence	14	14	13	12	11	11	11	11	11	11	11	11	11	2	1		
Levels	*I*	*I*	*II*	*III*	*IV*	*IV*	*IV*	*IV*	*IV*	*IV*	*IV*	*IV*	*IV*	*V*	*VI*		

This arrangement and analysis can also be viewed as digraph (directed graph) below as Figure 1.

The codes on nodes of digraph (Figure 1) are replaced with corresponding despritions to prepare a theoretical ISM model. ISM model generated created by SmartISM Software is re-drawn in EdrawMax software as Figure 2.

It is noteworthy that the barriers coded as 11 and 14 fall at *Level I*. Barrier coded as 9 falls at *Level II*. Barrier coded as 10 falls at *Level III*. Barriers coded as 2, 4, 5, 6, 7, 8, 12, 13 and 15 fall at *Level IV*. Barrier coded as 1 falls at *Level V*. Barrier coded as 3 falls at *Level VI*. In the ISM model, factors occupying the lowest level are the most important. In contrast, factors occupying top most level are the least important ones, and the factors that occupy middle levels of the model vary along the spectrum of importance i.e. the lowest middle part is relatively more important. In contrast, the upper central part is somewhat less critical.

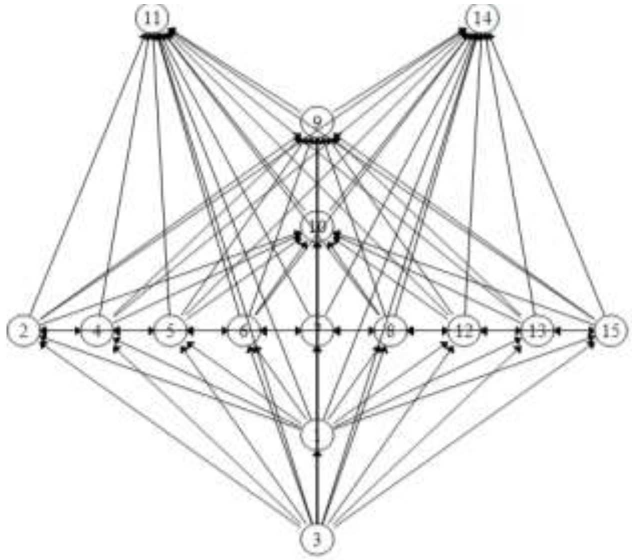

Figure 1: Digraph of Conical Matrix

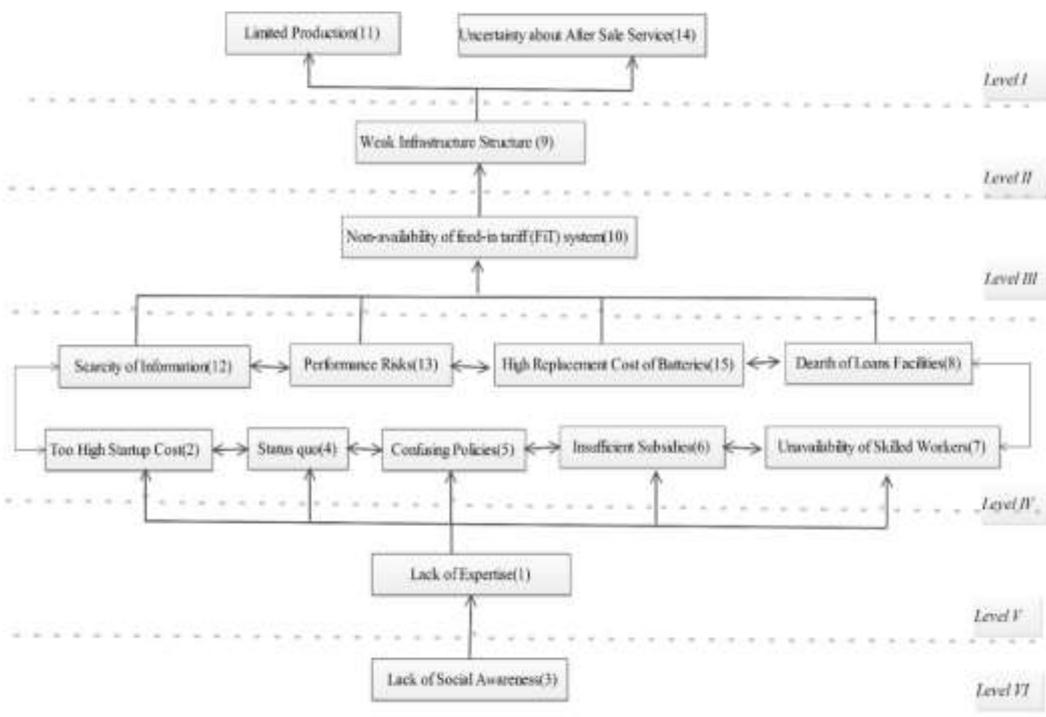

Figure 2: ISM Model

Source: Author's Constructed

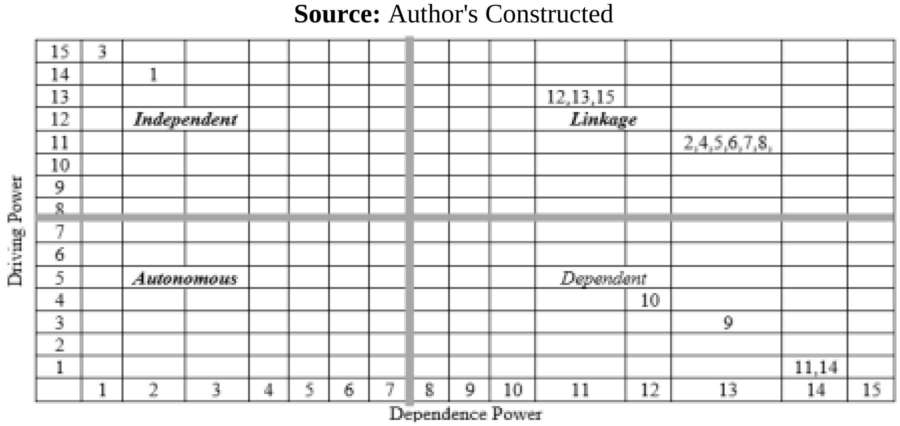

Figure 3: Driving-Dependence Diagram

Source: Authors Constructed

4.2. MICMAC Analysis

Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) classification (Figure 3) also is produced through SmartISM that follows the procedure introduced by Godet (1986). MICMAC is a technique that uses elementary Boolean algebra concepts and manipulates the factors' driving and dependence power. It classifies the factors into four different clusters on a Cartesian plane. There are two approaches to drawing MICMAC, scale-centric and data-centric. In this study, the scale-centric approach divides barriers along the continua of driving and dependence on power.

It can be observed from Figure 3 that the barriers coded as 1 and 3 fall in the independent cluster. Barriers coded as 9, 10, 11 and 14 falls in the dependent cluster. Barriers coded as 2, 4, 5, 6, 7, 8, 12, 13 and 15 fall in linkage cluster. There is no barrier categorized in autonomous cluster.

4.3. Results

Since switching to solar energy is vital for a country like Pakistan, switching to solar is subject to a lot of barriers. Therefore, the study at hand focused on the phenomenon. The study used literature discourse to unearth/uncover the barriers, ISM modeling the issue, and Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) analyzing the problem. As a result of the literature review, a list of fifteen factors (Table 1) is produced that is refined and approved by the panel of experts containing twentt-one members from among the stakeholders with sufficient expert knowledge of the domain. As a result of ISM modeling, barriers, namely limited production (11) and uncertainty about after sale service (14), fall at *Level I.* Barrier, namely weak infrastructure structure (9) falls at *Level II.* Barrier, namely non-availability of feed-in tariff (fit) system (10), falls at *Level III.* Barriers namely, too high startup cost (2), status quo with traditional sources (4), confusing policies for investors (5), insufficient subsidies/support (6), unavailability of skilled workers (7), dearth of loans facilities for solar setups (8), scarcity of authentic information (12), performance risks (13) and high replacement cost batteries (15), fall at *Level IV.* Barrier, namely lack of expertise (1), falls at *Level V.* Barrier, namely lack of social awareness (3), falls at *Level VI.* Barriers 11 & 14 lye at *Level I*, that's why they are the minor critical factors, whereas the factors that lye at the middle part of the model have a medium effect. The factors that lye at the bottom of the model are the most critical ones. Findings of Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) show that barriers, namely lack of expertise (1) and lack of social awareness (3), fall in an *independent cluster.* Barriers, weak infrastructure structure (9), non-availability of feed-in tariff (FiT) system (10), limited production (11) and uncertainty about after sale service (14), fall in a *dependent cluster.* Barriers namely too high startup cost (2), status quo with traditional sources (4), confusing policies for investors (5), insufficient subsidies/support (6), unavailability of skilled workers (7), dearth of loans facilities for solar setups (8), scarcity of authentic information (12), performance risks (13) and high replacement cost batteries (15) fall in *linkage cluster.*

According to MICMAC analysis, four classes of factors appear based on driving and dependence power; i) the linkage factors (that need special care) have high driving power and high dependence power, ii) the autonomous factors that have low driving power and low dependence power, iii) the independent factors (the most critical factors) have high driving power but low dependence power and iv) the dependent factors (the least critical factors) have low driving and high dependence power. A juxtaposed view of the literature review findings, ISM modeling, and MICMAC classification is provided as follows (Table 7).

Table 7: Juxtaposed View of Results

Results of Literature Review		Results of MICMAC Analysis			Results of ISM	Comment
Code	Issue	Driving	Dependence	Cluster	Level	
1	Lack of Expertise	14	2	Independent	*V*	Key factor
2	Too High Startup Cost	13	11	Linkage	*IV*	
3	Lack of Social Awareness	15	1	Independent	*VI*	Key Factor
4	Status Quo with Traditional Sources	13	11	Linkage	*IV*	
5	Confusing Policies for Investors	13	11	Linkage	*IV*	
6	Insufficient Subsidies/Support	13	11	Linkage	*IV*	
7	Unavailability of Skilled Workers	13	11	Linkage	*IV*	
8	Dearth of Loans Facilities for Solar Setups	13	11	Linkage	*IV*	
9	Weak Infrastructure Structure	3	13	Dependent	*II*	
10	No Feed-In Tariff System	4	12	Dependent	*III*	
11	Limited Production	1	14	Dependent	*I*	
12	Scarcity of Authentic Information	13	11	Linkage	*IV*	
13	Performance Risks	13	11	Linkage	*IV*	
14	Uncertainty about After-Sale Service	1	14	Dependent	*I*	
15	High Replacement Cost Batteries	13	11	Linkage	*IV*	

Table 7 shows that barriers to lack of expertise (1) and lack of social awareness (3) are critical factors since they occupy the bottom of the ISM model and fall in independent clusters. The key factors are marked grey and italicized in the table to distinguish them.

4.4. Discussion

This section of the paper discusses various aspects of the study. The discussion includes: discussion of results, implications, limitations, and recommendations for future research.

4.4.1. Discussion on results of the study

This study is based on an analysis of fifteen barriers to switching to solar energy systems (Table 1). The bottom-up approach of ISM modeling is applied to perform research and interpret the findings. As per the model developed herein, factors (barriers here) 11 & 14 falls at *Level I,* whereas factor 9 falls at *Level II*. Factor 10 falls at *Level III*, whereas factors 2, 4,5,6,7,8,12, 13 and 15 fall at

Level IV. Factor 1 falls at *Level V*, whereas factor 3 falls at *Level VI*. It is worth mentioning that the factors contained in *Level I* are the least important, and those held at *Level VI* are the most important ones.

ISM also reveals that apart from hierarchies, all the factors have two-way at-level relations except factor 11 and 14. In fact, 11 and 14 do not have direct relation at level. Transitive relations have been willfully skipped for simplicity (Warfield, 1973). ISM modeling divides elements into various levels, from most to least important, whereas Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC) divides them into four categories based on their driving and dependence factors. As per the MICMAC analysis, factors 1 and 3 are independent. Factor 9, 10, 11, and 14 are found to be a dependent factors. Factors 2, 4, 5, 6, 7, 8, 12, 13 and 15 are linkage factors, whereas no factor was autonomous. The factors that fall in the *independent cluster* are those with high driving power but low dependence power, which implies that independent factors (barriers in this case) can affect all others. The regulator needs to focus on controlling independent borders.

In contrast, the factor that falls in a *dependent cluster* has low driving power but high dependence power, which implies that the others drive them. If they control the independent barriers, the regulators will indirectly take control of these dependent variables. The factors (barriers in this case linkage cluster) have high driving and dependence power; therefore, they are considered agile, unbalanced, unsettled, or highly unstable. Any action by regulators will affect others and, in turn to themselves. The barriers that fall in *autonomous clusters are* considered irrelevant, dis-connected, and un-concerned with the system and may be eliminated if present. At the same time, they might have few but powerful direct or transitive relations/links to the other factors. Absence of the factors in this cluster tantamount that all the factors participating in the study are highly relevant and critical to the system under investigation. In this study, none of the barriers falls in this cluster, which means that all the barriers are appropriate and participate in the issue under study.

5. Conclusion

This is an exploratory and qualitative study based on a survey. The study aims to generate a list of factors that hinder switching to solar energy systems. The purpose of this study is to explore the barriers that bar consumers from switching to solar energy systems, thus hindering the development of and sustainable clean environment in Pakistan. The study reviews literature, primary data collection, and analysis. Methods used are literature discourse, ISM, and Matriced' Impacts Cruise's Multiplication Appliquee a U.N. Classement (MICMAC). From literature, a total of fifteen barriers were identified, refined & approved by the experts in the domain. The study barriers include lack of expertise (1), too high startup cost (2), lack of social awareness (3), status quo with traditional sources (4), confusing policies for investors (5), insufficient subsidies/support (6), unavailability of skilled workers (7), dearth of loans facilities for solar setups (8), weak infrastructure structure (9), non-availability of feed-in tariff (fit) system (10), limited production (11), scarcity of authentic information (12), performance risks (13), uncertainty about after sale service (14), high replacement cost batteries (15). According to ISM, lack of expertise and lack of social awareness are the key factors that appeared at the bottom of the ISM model. To be more precise, barriers coded as 11 and 14 fall at *Level I*. Barrier coded as 9 falls at *Level II*. Barrier coded as 10 falls at *Level III*. Barriers coded as 2, 4, 5, 6, 7, 8, 12, 13 and 15 falls at *Level IV*. Barrier coded as 1 falls at *Level V*. Barrier coded as 3 falls at *Level VI*. According to MICMAC, barriers coded as 1 and 3 fall in the independent cluster. Barriers coded as 9, 10, 11 and 14 falls in the dependent cluster. Barriers coded as 2, 4, 5, 6, 7, 8, 12, 13 and 15 fall in linkage cluster. There is no barrier categorized in autonomous cluster. Overall, factors 1 and 3 need special attention; actions on these variables affect other variables, thus affecting the entire system. In short, the study contributes a structural model, structural analysis, information on level-to-level and at-level information relations among barriers, and a crisp discussion on relations among barriers.

5.1. Implications of study

This part of the discussion explains the implications and contributions of the study, further organized into theoretical and practical implications.

5.2. Theoretical Implications

This study contributes to contemporary literature by adding a comprehensive list of barriers approved by the domain experts, thus, a founding stone upon which future research can be based. A structural model of barriers developed through ISM is a unique & exciting contribution of this study to literature. A classification of barriers through MICMAC is also an interesting contribution added by this study.

5.3. Practical Implications

The study has vast practical implications for many concerned stakeholders relating directly/indirectly to the issue. In emerging countries like Pakistan, where economies are in trouble due to an absence of resources necessary for development, the need for switching to renewable energy resources, i.e., wind power, solar energy systems, etc., is proportional. As per the study's findings, the regulators must focus on critical factors. They need to develop the required level of expertise in the field of harnessing and efficient use of solar power. The solar power marketing and installation companies can benefit from the study because they want consistent processes for marketing and installation of solar systems so that they can ensure the quality of their product. The large-scale producers/importers of solar energy may be interested in the study so that they can provide connections to the electric grids at accurate times. Overall, the focus on given factors would lead to the sustainable development of society at a smaller level and towards the country's sustainability in a broader sense. Lastly, the study is helpful for regulators, current & potential users, and industry since it provides a lot of new information and understanding about the phenomenon of vital and primary importance.

5.4. Limitations of study and recommendations for future research

This part of the discussion section discusses the limitations of the study and recommendations in order to overcome these limitations through future research. The limitations and recommendations of the study are as follows. Firstly the barriers identified here are based on a few experts' elicitations; though workable with ISM modeling (Sushil, 2017), future research can be replicated with as many as fifty-plus experts (Li et al., 2019). Secondly, as far as the methodology is concerned, the study is qualitative research open to verification through advanced statistical techniques like SEM, GRA, TOPSIS, and AHP. Thirdly, regarding the data, the data set required for this study is tedious to acquire in terms of time and experts' willingness.

Moreover, the questionnaire used to collect data is complicated that needs explanation in a one-on-one setting. Other advanced techniques like AHP and FUZZY-AHP can be applied to overcome the so-discussed limitation. Lastly, this study is based on the data set acquired in Pakistan; further research needs to be conducted in other countries or regions to get a rather more reliable results.

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