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Factors Hindering Solar Photovoltaic System Implementation in Buildings and Infrastructure Projects: Analysis through a Multiple Linear Regression Model and Rule-Based Decision Support System

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Abstract: Energy plays a predominant role in the development of society. With advancements in technology and the growth of society (buildings and infrastructures), the demand for energy is rapidly increasing. Developing countries typically rely on the import of fossil fuels and capital investments in infrastructure development to meet their energy needs. The execution of solar PV projects in developing countries is currently not being implemented promisingly. Therefore, the determination of the critical success factors hindering the implementation of solar PV projects is the need of the hour. The aim of this study is to determine the factors that hinder the implementation of solar PV projects through the use of a multiple linear regression model (MLRM) and a rule-based decision support system (RBDSS). Seven categories of factors were identified through a detailed literature review and interviews with energy experts. Four hundred and twenty-nine complete responses were collected in total through a questionnaire, and they were analyzed using relative importance indexing (RII) and MLRM and RBDSS approaches. A comparison was carried out against both methodologies to determine the most critical barriers to the implementation of solar PV projects. The findings regarding the MLRM approach showed that the top seven critical factors were economic conditions, encouraging policies, technological knowledge, organizational support, social awareness, market stability, and miscellaneous aspects. Similarly, the results for the RBDSS approach identified that the top seven critical factors were encouraging policies, economic conditions, organizational support, technological knowledge, market stability, social awareness, and miscellaneous aspects. The application of MLRM and RBDSS will help stakeholders in making timely decisions and corrections during the implementation phase, providing a systematic way to support the performance and execution of solar projects.

Keywords: renewable energy; buildings; infrastructure solar PV; barriers; multiple linear regression model (MLRM); rule-based decision support system (RBDSS)

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1. Introduction

A photovoltaic cell is a device that converts sunlight into electricity using semiconductor materials. Semiconductor materials enable the flow of electrons when photons from sunlight are absorbed, and then they eject electrons, leaving a hole that is filled by surrounding electrons. This phenomenon of the flow of electrons and photon absorption is called the photovoltaic effect.

A PV cell directs electrons in one direction, which forms a current, and the amount of current is proportional to the number of photons absorbed, which means that PV solar cells are a variable current source [1]. Monocrystalline silicon, polycrystalline silicon, and amorphous silicon (thin-film) solar cells are used for solar energy projects. Solar power projects provide speedy energy solutions to most of the energy crises faced by developing countries [2]. Solar energy solutions are one of the alternatives to the current generation of energy resources. Solar energy is also very promising in terms of ensuring clean and green energy provision because of its minimal gas emissions and other air pollutants [3]. The execution of solar power projects, however, faces various obstacles and difficulties due to a variety of factors. Previous studies and researchers have identified various barriers and hindrances and have suggested several measures and solutions for the successful implementation of solar projects [4]. However, these measures and solutions vary from country to country, as well as according to the economic condition and prevailing environment of each country.

Many studies have been conducted on renewable energy, especially on solar energy's potential in order to estimate its utilization in a country [5]. Shaikh et al. [6] focused on the importance of solar energy as a natural source in Pakistan. Farooq and Shakoor [7] recommended solar thermal energy as the best choice for the current energy crises in the country. Farooq and Kumar [8] evaluated the technical potential to generate electricity from solar PV technology. Mirza et al. [9] deliberated on the outlook and status of the exploitation of solar energy in Pakistan and highlighted the role of R&D in the development of solar energy in the country. Muneer et al. [10] defined the potential applications of solar thermal energy, i.e., solar water heaters for industry. Ghafoor and Munir [11] considered an off-grid PV system for domestic users. Some researchers found challenges associated with renewable energy [12–14]. However, no one has tried to utilize the identified factors in a multiple linear regression model (MLRM) and a rule-based decision support system (RBDSS) to determine the most critical success factors in the implementation of solar projects. Researchers have used MLRMs in various fields of study, e.g., the identification of factors affecting the results of the Chelsea football team [15] and an optimization algorithm based on data set denoising [16].

The current study utilized factors identified from studies in the literature for the development of a multiple linear regression model (MLRM) and a rule-based decision support system (RBDSS) to measure the effects, impact, and influence of each factor. A comparison of both methodologies was conducted to check the internal validity of the models. Stakeholders, policy makers, public and private firms, contractors, and consultants and project managers need to consider these factors/variables before planning an energy generation project. The effect of these factors on the successful execution of solar projects for buildings and utility-scale solar parks varies with the environment, economic conditions, and adoption of renewable energy resources by planners and practitioners [17]. The methodology and model developed can be used for the successful implementation of solar projects for buildings and solar parks in developing countries in general and Pakistan in particular. This methodology will help solar companies'/project managers to overcome the influence of critical factors and support their decisions with the aim of achieving a successful execution.

Solar energy plays a vital role in providing an alternate source of energy for the economic growth and development of society; however, its implementation has not been very promising in developing countries. Therefore, examining the critical barriers hindering the implementation of solar PV projects is direly needed. Previous studies have identified various factors hindering the implementation of solar PV projects and employed traditional methodologies, such as the mean score and relative importance index (RII), to measure the influence and impact. This research is novel and adds to the previous literature's use of modern techniques through the employment of a multiple linear regression model (MLRM) and rule-based decision support system (RBDSS) for measuring the weightage and influence of these critical hindering factors and through considering additional factors under the category of "miscellaneous aspects".

2. Literature Review

Identification of Major Factors Influencing Solar PV Implementation on Buildings and Utility Scale Projects

Researchers and scholars have identified numerous factors which are critically important for the successful implementation of solar projects [18]. These factors are identified as critical success factors (CSFs) for renewable energy projects. Kogila et al. have described that CSFs are especially important in achieving organizational goals [19]. CSFs are incredibly significant for any organization to achieve their targets, missions, and strategies as well as to improve the status of their society. In previous studies and literature, it was found that social factors, technology, government, economic conditions, organization and management, and environment are the CSFs that ensure the success of renewable energy projects.

Previous studies have identified major factors in the successful execution of solar projects, which include technological factors, economic factors, environmental factors, social factors, and miscellaneous factors [20]. Researchers have considered the impact of policies and innovation, technology, and technological changes in wind turbine and solar PV manufacturing industries in China and India. The studies show that the acceptance of solar PV projects is dependent on many factors, which include internal factors like technology awareness and intention of conserving energy and external factors such as cost, characteristics of the PV system, and the solar market [21]. PV is a socially acceptable technology because of its environmental value; however, its acceptance is dependent on the country's economic stability.

A study conducted by Jabeen et al. [22] on the socio-economic aspects of solar PV utilization in Pakistan shows that it can improve the quality of life in urban areas. Reddy and Painuly [23] have described that solar technology application is a suitable technology because of cost analysis and its user-friendliness. The research also confirmed that it has the potential to mitigate the energy crisis. Several studies concluded that higher income and higher education have a correlation with the decision to accept solar PV projects. Non-availability of the grid, mostly in developing countries, forces potential users to adopt solar technology more rapidly [24]. A study conducted by Vasseur and Kemp [25] on solar PV adoption and decision-making in households in the Netherlands resulted in four elements. These elements consist of technology advantage, innovation complexity, social inspiration, and cost and subsidies for solar systems.

It was established that cost was the main factor in decision-making for both adopters and non-adopters of solar PV systems [26]. The results of different studies confirmed that adopters of solar systems give more preference to cost than environmental issues when selecting solar PV systems [27]. Researchers also highlighted the existence of miscommunication and lack of awareness about the benefits of solar technology, potential adoption, and decision-making effects [28]. Another study conducted by Mirza et al. [29] finalized (i) policy factors, (ii) institutional factors, (iii) financial factors, (iv) market factors, (v) technological factors, and (vi) social factors as the renewable technology adoption factors in the context of Pakistan. Studies show that the low efficiency of current solar systems compared to conventional systems is the highest challenge in solar system development [30]. A study conducted by Painuly JP [31] finalized major factors in renewable energy adoption. These factors are, namely, (i) market failure/imperfection; (ii) market distortions; (iii) economic and financial; (iv) institutional; (v) technical; (vi) social, cultural, and behavioral; and (vii) other miscellaneous factors. Electricity generated through solar plants is not able to respond to electricity demand due to the parabolic pattern of solar energy generation. This issue does not come up in conventional systems [32]. Elena has highlighted that the major challenge for their application is the presumed negative impact on heritage value. Thus, the implementation of these projects is hindered by a social diffidence on their acceptability due to legislative, cultural, technical, and economic barriers [33].

In addition to the advantages of solar PV installation, it also has some drawbacks. Kut, P. and Pietrucha-Urbanik [34] have highlighted that failure in PV installations is the most-searched topic in scientific literature. The authors emphasized the technical, operational and reliability issues of solar PV installations. Damage or failure of some part of the solar power system forces the system to shut down until the replacement/repair of that component [35]. The application of solar PV systems in harsh environments (dusty or hot temperatures) may affect the output and efficiency of the solar PV system. The creation of hotspots may cause severe weakening of the PV system, thus resulting in higher maintenance costs. Costly initial investment in solar technologies leads to the creation of discontentment and dissatisfaction among potential manufacturers who fear investing [36]. Unawareness and incorrect information about the technology is a major challenge in the adoption of solar technology. The non-availability of land poses a great problem; sufficient land is required for the installation of power plants [37]. Dust accumulation and poor maintenance (cleaning) of solar panels also resulted in low efficiency [38]. The summary of main and sub-factors identified by pervious research as discussed above are shown in Table 1.

Table 1. Main and sub-factors—solar PV project implementations.

Main Factors	Sub-Factors/Variables	Reference
Market Stability	Availability of solar panels and accessories (ASE)	[2,3]
	After-sales service (ASS)	[17,18]
	No availability of skilled HR (NASHR)	[19,21]
	No standardization (NS)	[22,23]
	Market variation/cost variation (MV)	[24–26]
	No availability of testing laboratory (NTL)	[36]
Economic and Financial Condition	High initial investment (HII)	[4]
	Financing schemes (FS)	[14,15]
	Unawareness of market potential (UMP)	[17,18]
	Limited government tax exemption/subsidy (GTE)	[25]
	High financial risk (HFR)	[33,34]
Institutional/Organizational Support	Lack of institutional support (LIS)	[21]
	Cumbersome approval/sanctions process (CAP)	[22,23]
	Lack of vision and intent to grow solar industry (LV)	[26,27]
	Indigenous solar industry (LIS)	[29]
	Insufficient relief/exemption on import (IRI)	[36]
Technology Knowledge	Dependence on foreign technology (DFT)	[12,18]
	Poor assessment, incorrect design, and load demand (PAD)	[29,34]
	Poor maintenance and O&M (PO&M)	[39,40]
	Incorrect solar energy data and development (ISD)	[41]
	Unauthentic solar maps (USM)	[42]
Encouraging Policies	Confusing policies (CP)	[7,11]
	Feeble environmental structure (FES)	[14,22]
	No feed-in tariff system (NFIT)	[24,25]
	Lack of policy for solar firm registration/certification (LPSR)	[33]
	Lack of policy for solar awareness and promotion (LPSA)	[34]
	Lack of policy on training/education (LPSE)	[35]

Table 1. *Cont.*

Main Factors	Sub-Factors/Variables	Reference
Social, Cultural, Behavioral and Environmental Awareness	Lack of awareness about solar system, especially in rural areas (LAS)	[2]
	Lack of acceptance of modern technology (LAT)	[18,19]
	Lack of knowledge to manage and carry out repair and fixing (LKR)	[21]
	Lack of incentive to community for solar adoptions (LIC)	[37]
	Lack of training/education on solar (LTE)	[43,44]
Miscellaneous Aspects	Efficiency degradation due to poor maintenance and dust deposition (EDM)	[22,38]
	Uncertainties and unavailability of weather data (UWD)	[45–47]
	Lack of storage for non-grid-tied system (LS)	[48,49]
	Underinvestment in solar PV technology (LIS)	[50,51]
	Grid outage/non-availability of grid for solar PV adoption (GOS)	[52–54]

3. Methodology

Relevant literature related to solar project implementation on buildings (rooftops), infrastructures, and solar parks was used for the identification of various factors which highly influence solar project implementation. The literature was searched using the libraries of ASCE, Google Scholar, Taylor, Francis online, and Science-Direct. A keywords-based searching method was used, and some of the keywords used were "solar projects implementation", "solar on buildings (rooftop) projects", "decision support system in solar projects", "barriers in implementations", "factors affecting project performance as a search criterion within the areas of renewable energy", and "project management". The factors identified through literature studies are incorporated in statistical tool/software SPSS 26 for the formulation of a multiple linear regression model. The model measures the impact and influence of each factor and ranks and identifies most critical factors. In parallel, expert systems will be employed to find out the effects of these factors and their weightage in solar project implementation via input from 52 solar energy experts. The methodology of the multiple linear regression model (MLRM) and rule-based decision support system is explained as follows.

3.1. Multiple Linear Regression Model (MLRM)

Multiple linear regression (MLR) is a statistical method that uses the number of explanatory (independent) variables to predict the outcome of a response (dependent) variable. Multiple linear regression aims to model the linear relationship between the independent variables and dependent variables. The multiple linear regression model (MLRM) is used to determine a mathematical relationship among several random variables. In other terms, the MLRM examines how multiple independent variables are related to one dependent variable. Once each of the independent factors has been determined to predict the dependent variable, the information on the multiple variables can be used to create an accurate prediction of the level of effect they have on the outcome variable. The MLRM is used extensively in econometrics and financial inference. The formula for a multiple linear regression is shown in Equation (1) [55]:

$$y = \beta 0 + \beta 1X1 + \cdots + \beta nXn + \epsilon \quad (1)$$

y. the predicted value of the dependent variable;
β0. y-intercept (value of y when all other parameters are set to 0);
β1*X*1. the regression coefficient (β1) of the first independent variable (X1) (also known as the effect that increasing the independent variable has on the predicted y value);
βnXn. the regression coefficient of the last independent variable;
Є. model error (also known as how much variation there is in our estimate of y).

Previous studies have shown evidence of the use of the MLRM in various fields, including the solar industry. Researchers have used a multiple linear regression model in the performance analysis of traffic rules [56]. The MLRM is also used in psychological research to analyze the total LOS for patients undergoing laparoscopic appendectomy [57,58]. It is also used to estimate the power generation of a solar power plant with changing weather conditions and the probabilistic forecasting of solar power [59].

3.2. Rule-Based Decision Support System (RBDSS)

A number of studies have been carried out in the criteria-based design and utilization of decision support systems (DSSs) for solving decision-making problems of various nature [60]. Researchers have utilized DSS in project portfolio selection problem, resource allocation problem, manufacturing parts and tools in a production line and enterprise mergers and acquisitions scenario, respectively [61–65]. They have found promising results of DSS application. Literature has shown evidence of the use of DSS in solar PV project implementation and ascertaining the performance of various solar projects. The focus is mainly on the management of technical data (solar PV system) that relate to ascertaining the performance and various issues related to solar PV project implementation. A researcher has used a DSS for local neighborhood energy planning in Hague City, Netherlands. The model has facilitated multiple stakeholders in timely and correct decision-making process [66]. One researcher and his panel is of the view that DSSs are powerful tools which enable their users to carry out effective decision-making without involving themselves in technical details [67]. They have used DSS in the decision-making process of solar power system installation, monitoring monthly electricity expenses, return on investments, and site supervision. Another researcher has used DSS in the estimation of the photovoltaic potential of a building [68]. One researcher has made use of data from OpenStreetMap (OSM), volunteered geographic information (VGI), and a data-mining-based DSS for the estimation of potential individual residential building roofs. The researcher has used DSS through applying an analytic hierarchy process (AHP) and technique for order preference by similarity to an ideal solution (TOPSIS) for the site selection of solar power plants [43]. TOPSIS (a method of multi-criteria decision-making), is a way to allocate ranks on the basis of the weights and impact of the given factors. AHP is a structured technique for organizing and analyzing complex decisions based on mathematics and psychology [69]. A different researcher has used DSS while incorporating multiple criteria and a geographic information system (GIS) for improving building energy efficiency in Zielona Góra city, Poland.

3.3. Questionnaire Design

To rank, categorize, and validate the identified factors that influence the implementation of solar projects on buildings and infrastructure, a questionnaire-based survey was used, and various stakeholders and professionals from the solar industry were contacted to obtain their response. The questionnaire was designed in three parts. The first section was related to the personal information of respondents. The second section comprised a total of 37 sub-factors divided into 7 groups, as shown in Table 1. The third section consisted of suggestions and recommendations by respondents. A pilot study was used to measure the questionnaire 's content validity, practicality, and reliability. In this method, experts review all the items included in a questionnaire for their clarity and preciousness. Pilot studying is a normal procedure before conducting a questionnaire survey. The pilot study was conducted, and the questionnaire was shared with experts to acquire their reviews and comments. As per previous studies, a sample size of 8 is recommended for a pilot study [70]. So, 10 experts were requested for their valuable input. The identified factors were grouped into their respective main factors for better monitoring. Minor additions, deletions, and corrections were incorporated after experts reviewed the questionnaire. A reliability test was performed through measuring Cronbach's alpha to check the validity of questionnaire. As the value calculated was 0.946, this established the good reliability of the questionnaire. The respondents were contacted through email and personal visits.

Stakeholders of energy sectors, including academics, users, and clients, were also included in the participants to have their input on the subject. All the experts were requested to rate a given factor according to a Likert scale (from 1 to 5) for all the identified factors with respect to their effect on solar project implementation separately. A rating of "1" shows the lowest impact, "3" depicts moderate impact, and "5" shows the highest impact [71]. Around 500 questionnaires were distributed, and 429 responses were received with an overall response rate of 85.8%. The experience of all experts was between 8–15 years. The reliability of the questionnaire instrument was analyzed through Cronbach's alpha test for statistical analysis and ranking of the data obtained from survey results [72–75]. Spearman's correlation test was performed to analyze the strength of relationships between factors. Regression, ANOVA, and the relative importance index (RII) were applied for the weightage and influence of each factor.

3.4. Reliability Analysis

The reliability and validity of data collected from the questionnaire was ensured through reliability analysis. Cronbach's coefficient alpha (a) was used to test the internal consistency among items included in each factor [76]. The alpha (a) calculated for organizational support was 0.867; miscellaneous aspect 0.865; encouraging policies, 0.853; economic condition factors, 0.816; market stability, 0.801; social awareness, 0.798; technological knowledge, 0.788; while 0.813 was the score for project implementation factors. A value of 0.7 is sufficient to justify reliability. The overall a value for 44 factors was 0.946. The results are highlighted in Table 2.

Table 2. Reliability statistics of factors.

Factors	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
Market Stability	0.946	0.801	6
Economic and Financial Condition		0.816	5
Institutional & Organizational Support		0.867	5
Technical and Technological Knowledge		0.788	5
Social and Cultural Awareness		0.798	5
Encouraging Policies		0.853	6
Miscellaneous Aspects		0.865	5
Project Implementation		0.813	7

3.5. Questionnaires Distribution and Responses

The questionnaires were distributed to target populations after the pilot study, including manufacturers, suppliers, financiers'/financing institutes, contractors, government organizations, academics, and users/clients involved in various solar projects being implementing in the country (both building and utility scale). Approximately 117 solar companies are registered with the Alternate Energy Development Board (AEDB) and Pakistan Engineering Council (PEC) under different categories and are involved in solar projects. According to subject matter experts of the solar industry, a minimum of 30–50 responses per category of sample was enough with ±10% sampling error and a 95% score obtained from the questionnaire survey as used in other studies. The response rate of contractors was 85.7%; consultants, 83.33%; government, 90%; and academia, 85%. The results received from various respondents are shown in Figure 1. According to previous studies, a response rate between 20–91% is good for the service and production sector. The respondents were asked to give separate inputs regarding the impact of identified factors on solar project implementation.

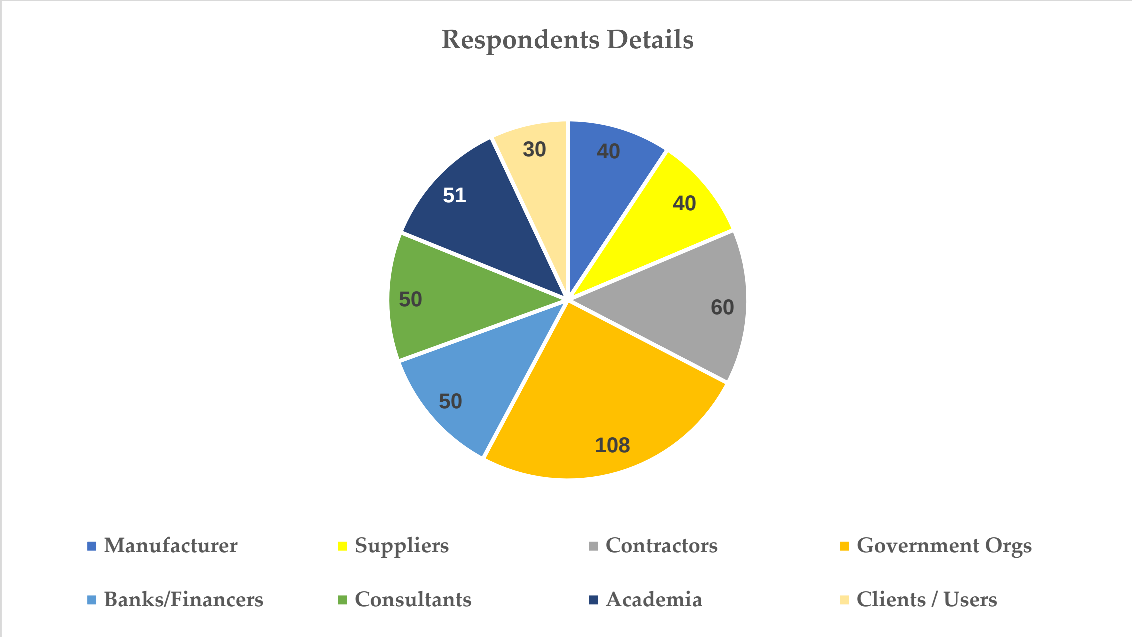

Figure 1. Respondents' details.

4. Results and Findings

The results and findings from various methodologies are discussed in the ensuing paragraphs.

4.1. Relative Importance Index (RII)-Based Findings

The influencing factors are given importance/ranking based on the mean score and their relative weight [77]. The value is computed with the formula as shown in Equation (2). The weight of each variable is ranked as per the severity and impact as given in Table 3.

$$RII = \Sigma W/(A \times N) \quad (2)$$

where W is the weighting given to each factor by the respondents (ranging from 1 to 5), A is the highest weight (i.e., 5 in this case), and N is the total number of respondents (i.e., 429 in this case). The higher the value of RII, the more important the impact or influence of the factor. The graphical illustration of the relative importance index is shown in Figure 2.

Table 3. Relative importance index (RII)—factors influencing solar projects' implementation.

Variables/Factors	Mean	Std. Deviation	RII	Ranking
Lack of vision and intent	3.39	1.21	0.812	1
Lack of policy for solar awareness	3.78	1.02	0.811	2
No feed-in tariff system	3.47	0.85	0.794	3
Underinvestment in solar	3.69	1.01	0.793	4
Unauthentic solar maps	3.38	0.85	0.785	5
Efficiency degradation	3.62	1.04	0.784	6
Feeble environmental structure	3.48	0.91	0.772	7
Lack of storage for non-grid-tied system	3.33	1.33	0.772	8
Government tax exemption/subsidy	2.56	1.31	0.765	9
After-sales service	3.24	0.88	0.764	10
Confusing policies	3.55	0.98	0.748	11
Unavailability of weather data	3.35	1.15	0.748	12
High financial risk	2.89	1.16	0.743	13
Lack of policy for solar firm registration	3.51	0.77	0.742	14
Grid outage/non-availability of grid	3.37	1.07	0.742	15

Table 3. *Cont.*

Variables/Factors	Mean	Std. Deviation	RII	Ranking
No availability of skilled HR	3.72	0.74	0.738	16
Cumbersome approval/sanctions process	3.14	1.08	0.736	17
Lack of institutional support	2.86	1.27	0.736	18
High initial investment	3.95	0.91	0.721	19
Financing schemes	3.11	1.09	0.720	20
Unawareness of market potential	3.38	0.99	0.719	21
Incorrect solar energy data	3.32	0.96	0.710	22
Lack of policy on training	3.34	0.82	0.710	23
Availability of solar panels	3.22	0.91	0.703	24
Lack of awareness	3.02	1.17	0.695	25
Indigenous solar industry	3.48	0.85	0.695	26
No standardization	3.38	0.71	0.693	27
No availability of testing laboratory	4.03	0.76	0.684	28
Market variation/cost variation	3.64	0.71	0.680	29
Lack of acceptance of modern technology	3.04	0.91	0.662	30
Insufficient relief/exemption on import	2.88	1.30	0.662	31
Poor assessment, incorrect design	3.19	0.85	0.661	32
Lack of policy for registration	2.83	1.15	0.660	33
Lack of policy for standardization	2.66	1.30	0.658	34
Lack of knowledge for repair and maintenance	3.00	0.93	0.658	35
Dependence on foreign technology	3.14	0.91	0.658	36
Poor maintenance and O&M	3.41	0.82	0.655	37

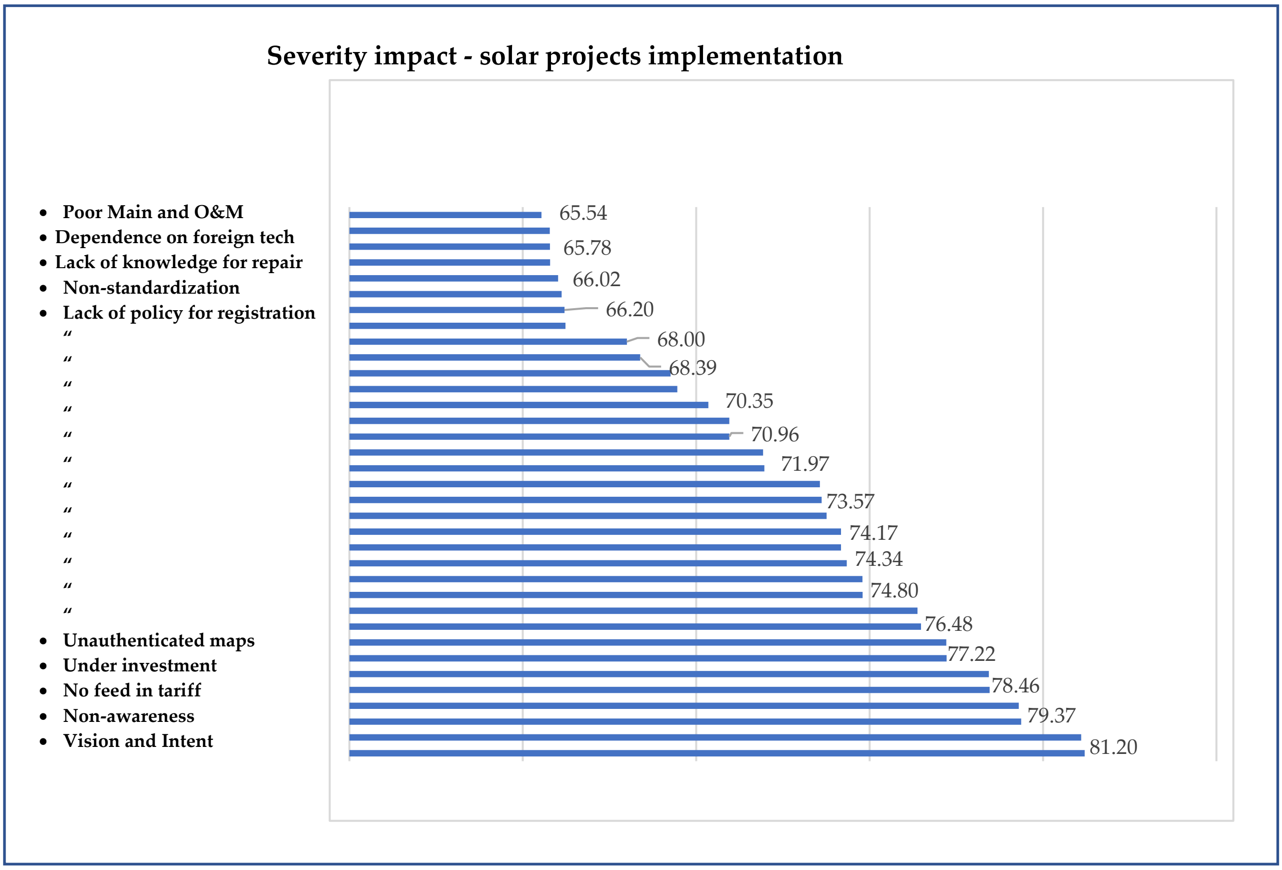

Figure 2. Relative importance index (RII)—factors influencing solar projects' implementation.

The result of the mean score and relative importance index has shown that vision and intent to implement solar projects is the most influencing and critical factor (RII 0.8120);

the second most influencing factor is non-awareness (RII 0.811) and the third is no feed-in tariff policy (RII 0.794), followed by under-investment (RII 0.793) and unauthenticated solar maps and solar data (RII 0.785), respectively. Meanwhile, low influencing factors are poor maintenance and O&M (RII 0.655), dependence on foreign technology (RII 0.658), lack of knowledge (RII 0.6584), standardization (RII 0.6582), and policies for firm registration (RII 0.6581), respectively. The results of this study confirmed the impact and influence of sub-factors on the implementation of solar projects are the same as highlighted and confirmed by previous studies. Aqeeq et al. [78] highlighted that the efficient provision of low-cost and long-term financing can help in the implementation of solar projects in developing countries. Gautam and Sunanda et al. [36] deliberated upon policy and innovation in the implementation of solar projects. Irfan et al. [20] have stressed about awareness campaigns that highlight the importance of energy conservation and reducing greenhouse gas emissions. Tareq et al. [4] focused on various strategies to increase the adoption of solar technology. The impact and influence of other sub-factors are highlighted in Table 3.

4.2. Multiple Linear Regression Model (MLRM)-Based Findings

Responses from 429 respondents were used for the development of an MLRM through a survey-based questionnaire. Responses were processed in SPSS 26 for statistical analysis. Results of Spearman's correlation established a moderate to strong positive correlation between major factors. The most impactful and influential factors are economic conditions (R square weigh-age 0.501), encouraging policies (0.437), technological knowledge (0.356), organizational support (0.343), and social awareness (0.322), respectively, whereas a weak positive correlation exists between market stability (0.267) and miscellaneous aspects (0.238), respectively, in solar project implementation. The correlation coefficients obtained are quite rational as financial conditions and encouraging policies are directly interlinked with each other. The results of studies confirmed the categories and ranking of most critical success factors in the implementation of solar projects [20,21,29]. The stable economic and financial condition of a country, encouraging policies, knowledge of and acquaintance with technology, organization support, and social awareness help in the implementation of solar projects in any environment/country [22,23]. Through effective control of legislative, cultural, technical, and economic barriers, the implementation of solar projects can be increased [33]. Results of sub-factors are shown in Table 4.

Table 4. Results—MLRM and RBDSS.

S NO	Factors/Sub Factors	MLRM	Rank	RBDSS	Rank	Overall Rank
1	Market stability (MS)					
1a	Availability of solar panels and accessories (ASE)	0.190	18	0.373	16	18
1b	After-sales service (ASS)	0.142	38	0.211	31	38
1c	No availability of skilled HR (NASHR)	0.205	15	0.431	13	15
1d	No standardization (NS)	0.162	27	0.283	26	27
1e	Market variation/cost variation (MV)	0.166	24	0.317	23	24
1f	No availability of testing laboratory (NTL)	0.183	20	0.341	18	20
2	Economic and financial condition (EC)					
2a	High initial investment (HII)	0.187	19	0.363	17	19
2b	Financing schemes (FS)	0.354	3	0.321	22	3
2c	Unawareness of market potential (UMP)	0.432	1	0.587	1	1
2d	Limited government tax exemption/subsidy (GTE)	0.281	6	0.211	30	6
2e	High financial risk (HFR)	0.388	2	0.431	12	2
3	Institutional/organizational support (OS)					
3a	Lack of institutional support (LIS)	0.163	26	0.299	25	26
3b	Cumbersome approval/sanctions process (CAP)	0.177	21	0.331	19	21
3c	Lack of vision and intent to grow solar industry (LV)	0.132	35	0.132	35	35
3d	Indigenous solar industry (ISI)	0.159	28	0.261	27	28
3e	Insufficient relief/exemption on import (IRI)	0.165	25	0.301	24	25

Table 4. *Cont.*

S NO	Factors/Sub Factors	MLRM	Rank	RBDSS	Rank	Overall Rank
4	Technical/technological knowledge (TK)					
4a	Dependence on foreign technology (DFT)	0.271	7	0.551	4	7
4b	Poor assessment, incorrect design, and load demand (PAD)	0.128	36	0.117	36	3
4c	Poor maintenance and O&M (PO&M)	0.081	37	0.095	37	37
4d	Incorrect solar energy data (ISD)	0.203	17	0.391	15	17
4e	Unauthentic solar maps (USM)	0.212	13	0.471	10	13
5	Social, cultural, behavioral, and environmental awareness (SA)					
5a	Lack of awareness about solar power (LAS)	0.138	33	0.187	33	33
5b	Lack of acceptance of new technology (LAT)	0.169	23	0.323	21	23
5c	Lack of knowledge to manage and carry out repair (LKR)	0.145	30	0.211	29	30
5d	Lack of incentive to community for solar adoption (LIC)	0.139	32	0.203	32	32
5e	Lack of training/education on solar (LTE)	0.146	29	0.243	28	29
6	Encouraging policies (EP)					
6a	Confusing policies (CP)	0.238	5	0.577	2	5
6b	Feeble environmental structure (FES)	0.291	4	0.567	3	4
6c	No feed-in tariff system (NFIT)	0.225	11	0.496	8	11
6d	Lack of policy for solar firm registration (LPSR)	0.204	16	0.411	14	16
6e	Lack of policy for solar awareness and promotion (LPSA)	0.270	8	0.541	5	8
6f	Lack of policy on training/education on solar (LPSE)	0.211	14	0.451	11	14
7	Miscellaneous aspects (MA)					
7a	Efficiency degradation/poor maintenance (EDM)	0.170	22	0.329	20	22
7b	Uncertainty and unavailability of weather data (UWD)	0.223	12	0.483	9	12
7c	Lack of storage for non-grid-tied system (LS)	0.137	34	0.137	34	34
7d	Underinvestment in solar PV technology (UIS)	0.242	10	0.501	7	10
7e	Grid outage/non-availability of grid (GOS)	0.261	9	0.531	6	9

4.3. Rule-Based Decision Support System (RBDSS)-Based Findings

Fifty-two subject matter experts of the solar industry were invited to register their inputs and insights. The participants were explained in detail regarding the use of the expert system. The inputs/opinions were captured and populated into a rule-based expert system. The experts gave the weightage to each factor. The final weights of the primary independent variable are calculated using the system itself. The order of importance of all variables and primary factors were calculated through the average weight calculation of the input received from experts as shown in Table 4. RBDSS models have established the impact and influence of each factor and their sub-factors as per weightage. The result of RBDSS show the most critical factors, which are categorized and ranked as follows: encouraging policies (average weightage score 0.811), economic conditions (0.751), social awareness (0.711), miscellaneous aspects (0.660), organizational support (0.635), technological knowledge (0.610), and market stability (0.595). The results of RBDSS categorization and ranking varies from MLRM results. The experts of the energy sector have ranked encouraging policies as the main driving force in the implementation of solar projects, whereas as MLRM shows, economic condition is main influencing factor. From the perspective of developing countries, economic conditions are a most influential and deciding factor for the implementation of solar projects [4,14,26]. Comparative results of MLRM and RBDSS are shown in Table 4.

4.4. Comparative Findings Based on RII, MLRM, and RBDSS

A comparison of all three methodologies is shown in Table 5. Rankings based on the weightage, influence, and impact on the implementation of solar projects are compared, and the overall ranking of these factors is also illustrated. Economic conditions and encouraging policies are the most influencing factors, whereas organizational support, technological knowledge, and social awareness are equally important with regard to the implementation of solar projects. Last but not least, miscellaneous aspects, once combined with other factors, also induce deciding effects in the implementation of solar projects in building- and utility-scale projects.

Table 5. Comparison—RII, MLRM, and RBDSS.

S NO	Factors	RII	Rank	MLRM	Rank	RBDSS	Rank	Overall Rank
1	Market stability (MS)	0.710	5	0.267	6	0.595	7	6
2	Economic conditions (EC)	0.733	2	0.501	1	0.751	2	1
3	Organizational support (OS)	0.728	4	0.343	4	0.635	5	4
4	Technological knowledge (TK)	0.693	6	0.356	3	0.610	6	3
5	Social awareness (SA)	0.696	5	0.322	5	0.711	3	5
6	Encouraging policies (EP)	0.767	1	0.437	2	0.816	1	2
7	Miscellaneous aspects (MA)	0.667	7	0.238	7	0.660	4	7

5. Discussion

The significance and novelty of this research is the application of a methodology that is the integration of MLRM and RBDSS, which will be used to assess solar projects' implementation in buildings and solar parks. A thorough understanding of engineering management practices in the solar industry is the contribution of academics. The in-depth literature review of solar projects implementation disclosed the need for more pragmatic research on project management skills. This study will connect earlier-conducted studies and prospective research on the root causes of solar project implementation in developing countries.

5.1. Influence of Economic and Financial Condition (EC) on Solar Project Execution

According to results of MLRM and RBDSS, the economic and financial condition of a country is a very important factor for the success of any project. Without strong financial condition and economic stability, it is difficult to ensure the implementation and execution of other factors, the provision of subsidies, tax exemption, relief and relaxation in imports, and the promotion of awareness among the masses. The results of this study are in line with studies conducted on "Solar Energy Development in Pakistan: Barriers and Policy" [20]. According to Climate Council Report 2019, the secret behind Uruguay and Sweden's success in the field of solar energy is "Clear decision-making, a supportive regulatory environment, and a strong partnership between the public and private sector". Sweden has been continuously investing in solar, wind, energy storage, smart grids, and clean transport. Sweden is aiming to be the first fossil-fuel-free country in the world [79]. Developed countries, in this regard, can help developing countries in the provision of financial capital, transfer of technologies, and sharing the latest R&D and skilled human resources. Developing countries can set their priorities for gradually shifting from traditional sources of electricity generation to renewable energy generation. Therefore, the lack of a stable economy and financial condition can adversely impact solar project implementation. Financial stability and availability of funds is one of the most important part of any solar project, if cash inflow is not on time then the project can never meet its timelines and its conceptual objectives. As the quantum of investment in a typical solar project are quite high and the solar firm can only invest a specific amount (equity) from its own resources in the project therefore assurance of secure funding from the client/government is the foremost importance for execution and implementation of an energy project. Sub-factor related to economic conditions such as awareness of solar market potential is most impacting and influential factor. Muntasser M et al. [24] have confirmed this aspect in their study. The high financial risk is another important sub-factor that plays a key role in the selection and adoption of solar projects [26]. Similarly, financial schemes for implementation of solar projects helped in the adoption of solar projects more quickly.

5.2. Influence of Encouraging Policies (EP) on Solar Project Execution

According to the survey and MLRM, encouraging policies was rated as the second most influential major factor that impacts solar project execution in developing countries, while as per DSS and RII, it is the second most impacting factor, respectively. Encouraging policies create an environment for the implementation and execution of projects and help in the achievement of intended objectives. Encouraging polices draw their strength from the stable and strong financial conditions of a country. Encouraging policies are planned with a view of future objectives/aims. Accordingly, required relief, relaxation, and provision are provided to potential investors/executors. According to NREL—Technical Report (2013), the USA used the BEPTC and SROPTTC [80] framework during pre-development and in the development phase for solar project implementation. Results of this study are in line with previous studies conducted on the subject [10,11,19,24]. Developing countries can plan their future energy generation requirements through renewable energy resources in a phase-wise program. They can fix an annual target or milestone; all policies and facilitations are planned according to a milestone. Moreover, plan policies must have clarity among potential users; all ambiguity and doubts of investors must be addressed. The current RE policy [44,81] in Pakistan does not address the objectives and aims of the Government of Pakistan. Leading countries of world, i.e., China, USA, Germany, and India, have planned and enforced encouraging policies for the attainment of their future objectives as well as a vision regarding energy generation [10,29]. Sub-factors interrelated with a lack of encouraging polices, such as a feeble environmental structure, impact solar technology adoption [20]. Another sub-factor impeding solar projects' implementation is confusing policies, both for users as well as for investors [14]. The lack of a policy for solar technology awareness is another sub-factor which extremely impacts solar technology adoption [17].

5.3. Influence of Technical and Technological Knowledge on Solar Project Execution

According to the survey and MLRM results, technical and technological knowledge (TK) was rated as the third most influential major factor that impacts solar project execution in developing countries, while as per DSS and RII, it is the sixth most influential factor. Technical understanding and technological knowledge provide awareness and create know-how for the acceptance and ultimate use of the technology. Technological knowledge provides awareness and makes society well informed to understand the benefit of technology. Misconceptions and wrong information about technology can be removed with interactive promotions, seminars, and technological workshops. This study confirm that technical and technological knowledge is one important factor which impacts and influences the implementation of solar projects as highlighted in previous studies [19,24,34]. Creation of requisite knowledge and information about technology among the masses helped Germany and Cost Rica accept technology more easily and ultimately helped in the implementation of renewable projects [79]. Sub-factors allied to technical knowledge also have a negative impact on solar technology adoption, such as poor assessment and incorrect design, dependence on foreign technology, and unauthenticated solar maps for correct assessment [45–47,50,78,82–84].

5.4. Influence of Institutional and Organizational Support on Solar Project Execution

According to the survey and MLRM results, institutional and organizational support (OS) was rated as the fourth most influential major factor that impacts solar project execution in developing countries, while as per DSS and RII, it is rated the fifth and fourth most impactful factor, respectively. Institutional and organizational support provide facilitation at a tactical level in the provision of organizational resources, authority, and HR. It provides guidance and help in obtaining different reliefs, exemptions, approval, permits, and subsidies to expedite the execution and implementation of solar projects. Organizations and institutions can help in planning and implementing solar projects through public–private partnerships. Organizations and institutions can take lead roles in educating and creating awareness among masses. This study confirms the influence of organizational support in the implementation of solar projects. Organizational support acts as catalyst in the implementation of a solar project. Leading solar countries like the USA, Japan, France, and Italy encouraged organizational support for the implementation of solar projects [79,80]. Sub-factors coupled to organizational support also impact solar adoption adversely, such as a cumbersome approval process, delay in implementation, insufficient relief causing fear in the minds of investors, and a lack of institutional support; these spoil the whole process [53,54].

5.5. Influence of Social, Cultural, Behavioral, and Environmental Awareness on Solar Project Execution

According to the survey and MLRM results, social, cultural, behavioral, and environmental awareness (SA) was rated as the fifth most influential major factor that impacts solar project execution in developing countries, while as per DSS and RII, it ranked third and fifth, respectively. Social, cultural, behavioral, and environmental awareness (SA) creates an atmosphere and makes a path for the acceptance of a new technology and modern trends. In developing countries, the acceptance and adoption of new technologies and modern trends are at a slow pace. However, if a proper promotion and media campaign is conducted, awareness among society can be created and the acceptance ratio for new trends and technologies can rapidly increase. Developed countries have taken special care and focused on promotion and social awareness [79,80]. A proper media campaign for the benefit of the use of solar technology and renewable energy resources and a clearance of misconceptions and delusions is the need of hour. This will create a roadmap and a conducive environment for the acceptance of new technology and ultimately help in the implementation of a project. The results of this study are in line with previous studies conducted on subject technology (ranked 23), lack of training and solar education (ranked 29), and lack of knowledge to carry out repairs [24,35]. Sub-factors associated with social awareness, such as lack of acceptance of new repairs (ranked 30), do have an impact and influence solar technology adoption [40,52].

5.6. Influence of Market Stability on Solar Project Execution

According to the survey and MLRM results, market stability (MS) was rated as the sixth most influential major factor that impacts solar project execution in developing countries. However, as per DSS and RII, it is ranked seventh and fifth, respectively. Market stability is the first indicator of a stable economy. Uncertain and fluctuating market conditions create confusion and chaos in the minds of investors. Developing countries are usually facing such conditions more frequently. Foreign donors, investors, and developers fear investment in such an environment. Economic conditions and encouraging policies can help stabilize market conditions in a country. A stable market and strong economy help in the acceptance of modern technology more easily and help in the implementation of a project. Results of this study are in line with previous studies [23,27]. Sub-factors connected to market stability such as skilled HR (ranked 15), availability of solar accessories (ranked 18), and non-availability of testing laboratory (ranked 20) may also have a negative influence on solar technology adoption [5,8,11].

5.7. Influence of Miscellaneous Aspects on Solar Project Execution

According to the survey and MLRM results, miscellaneous aspects (MA) were rated as the seventh most influential major factor that impacts solar project execution in developing countries, while as per DSS and RII, it is also ranked seventh and fourth, respectively. Miscellaneous aspects do have an impact and influence on solar projects. These are contributing factors; miscellaneous aspects influence solar adoption more pronouncedly when combined with main factor synergies. While planning solar projects, miscellaneous aspects also require focus and may be addressed in a professional manner to obtain desirable results. Miscellaneous aspects, though, have a small impact on solar project implementation, but once combined with main factors, they have greater influence and impact. The results are in line with previously conducted studies [35,36]. Sub-factors linked to miscellaneous aspects such as grid outage (ranked 9), under investment (ranked 10), and uncertainties of weather data (ranked 12) pose an undesired impact on solar technology adoption [3,18,21].

6. Conclusions and Recommendations

The present study aimed to identify key factors affecting solar project implementation. The study ranked various factors according to their impact and influence. The key factors were identified through a literature review and finalized after consultation with energy experts. A total of 7 major factors and 37 sub-factors grouped into seven categories were incorporated in the questionnaire. Later, the questionnaire was conducted, and solar and energy sector professionals and stakeholders were asked to quantify the influence of these individual factors on solar project implementation. The top seven most critical factors, categorized and ranked based on the MLRM results as per their weights and impact, were economic conditions, encouraging policies, technological knowledge, organizational support, social awareness, market stability, and miscellaneous aspects. Similarly, results based on RBDSS categorized factors as encouraging policies, economic conditions, organizational support, technological knowledge, market stability, social awareness, and miscellaneous aspects.

Therefore, it safe to say that successful implementation of a solar project in buildings and solar parks can be achieved through efficient planning, effective promotion and awareness campaigns, innovative and encouraging and futuristic polices, and monitoring and controlling the identified factors. Results achieved through MLRM and RBDSS are in line with critical success factors identified by various researchers. Developing countries can control and address these factors for the successful implementation of solar projects for both domestic- (buildings, rooftop) and utility-scale projects.

Solar technology is one of the technologies which is abundantly available in nature. Key factors identified in studies are identical to the critical success factors of renewable energy. Effective and judicious controlling of these factors and planning to gradually transition from traditional sources of energy generation to renewable (solar) sources of energy generation may help developing countries in addressing their energy issues. The following are recommendations based on the findings and results of this study.

- Developing countries can set their priorities for gradually shifting from traditional sources of electricity generation to renewable energy generation. As the initial cost of a solar project is quite high and investment in solar project requires sovereign guarantees and payment sureties, assurance of secure funding from the client/government is therefore of foremost importance. Small-scale solar projects like ones applied on a building's rooftop can be facilitated through solar financing schemes.
- Developing countries can plan their future energy requirements at both domestic (on buildings) and utility scales through solar PV projects in a phase-wise program. They can plan an annual target or milestone and, accordingly, all policies and facilitations may be planned according to a milestone (target).
- High initial investments for solar projects can be arranged through executing projects as public–private partnerships.
- Banks and financing institutes can provide loans, subsidies, and micro-financing for solar projects on buildings and utility-scale projects. Governments can provide various schemes, tax exemptions, and relief to the solar industry and domestic users.
- The far-flung areas of the country, i.e., Gilgit Baltistan (GB), Khyber Pakhtunkhwa (KP), and rural areas in Sindh and Baluchistan, which are away from the national grid, can make use of these subsidies and benefit from microfinancing for acquiring the benefits of solar PV projects in homes, buildings, and infrastructures.
- There is a need to educate the masses about the benefit of the use of new technologies like solar, wind, and biogas. This can be achieved through launching interactive awareness campaigns to highlight the importance of energy-efficient buildings (solar on the rooftop) and reducing greenhouse gas emissions.
- All stakeholders of the construction industry, energy sector, government organizations, and academia should work synergistically and coherently to increase the use of solar energy at the domestic (building) and industrial levels (solar parks).

- Domestic users and clients can be influenced through attractive incentives, subsidies, and loans to purchase solar energy solutions according to their needs and requirements.
- The agricultural sector of the country can be boosted through the provision of solar schemes for the conversion of water pumps and tube wells into solar-powered ones through rebated loans and subsidies.
- Policy frameworks should be improved through giving more priority to renewable energy projects instead of conventional energy projects.
- Promotional campaigns through media, interactive workshops, lectures, seminars, and signposting can increase awareness among the masses and facilitate the adoption of new technology.
- There is a need to establish local training centers for solar technology learning. Advanced studies at the college and university level will help in preparing the required skilled human resources.
- The establishment of indigenous solar manufacturing facilities will help in mitigating the cost of solar equipment and help in research and development in solar technology.
- The standardization of solar equipment, firms' registration, and one-window operation for the facilitation and approval of solar projects will build confidence and increase the adoption and implementation of technology.

The practical implication of this study is to establish a guideline for key factors associated with solar project implementation. The finding of this study will assist solar industry professionals and stakeholders during solar project planning, implementation, and execution. This will help in planning and executing a gradual transition from traditional sources of energy generation to renewable generation of electricity for both domestic and utility-scale projects.

7. Limitations and Future Studies

This research has some limitations which need to be addressed. This study has applied a multiple linear regression model (MLRM) and rule-based decision support system (RBDSS) for measuring influence and impact. Future studies may utilize other advanced techniques such as artificial neural network (ANN)-based modelling and analytical hierarchical process (AHP) for determining the factors which influence solar project implementation. The focus of this study was the implementation of solar projects on buildings (rooftop) and utility-scale solar projects. Off-grid and storage (batteries)-based solar projects were not included in the study. Future scholars may investigate off-grid and storage (batteries)-based solar projects. They can also conduct empirical studies to validate the effectiveness and practicality of the proposed approaches in real-world settings. Additionally, future studies may examine the scalability and adaptability of the suggested approaches to different contexts and regions to get valuable insights. Future research work may explore and synergize with related research areas and investigate interdisciplinary collaborations to broaden the scope and impact of the current study.

8. Contribution of the Study

The contribution of this study is the application of a methodology that is the integration of MLRM and RBDSS for measuring the influence, impact, and weightage of each factor. Previously, traditional techniques and methods were used for measuring the impact of critical hindering factors. The critical success factors identified by Kogila et al. [19] are re-organized in this study with additional factors, i.e., miscellaneous aspects.

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