

Are we really addressing the roadblocks to adoption of renewable and sustainable energy technologies? Total Interpretive Structural Modeling approach

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Abstract: Urban areas serve as a vital contribution to the global structural change towards renewable and sustainable energy technologies which also influences climate change. The primary purpose of this paper is to identify the adoption roadblocks to renewable and sustainable urban energy technologies. This research has three parts: A mini-systematic literature study was conducted to identify the most prevalent roadblocks. Using Total Interpretive Structural Modeling (ISM), the relationships between the roadblocks and the source of causation were then examined. The roadblocks are classified based on their dependence and driving powers using MICMAC Analysis in the third part of this research. The principal results and major conclusions demonstrate that dependent roadblocks to renewable and sustainable energy technologies are defined as lack of coordination among authorities, lack of information, and competition with non-renewable technologies. Moreover, linkage roadblocks have high dependence and driving powers which are insufficient infrastructure, limited awareness and consumer interest, and lack of standardized technology. Lastly, high initial investment cost, lack of subsidies and financial support programs, Absence of coherent related policies, and Lack of skilled and trained personnel are the driving roadblocks with high driving power however not dependent.

Keywords: Urban energy systems; Sustainable energy technologies; Climate change; Sustainability; Renewable energy technologies.

1. Introduction

Globally, increasing energy demand and consumption, particularly of fossil fuels (coal, oil, and gas) in the urban and industrial sectors, is the primary driver of increased Greenhouse gas (GHG) emissions (Shadman et al. 2022). Thus, 75% of global energy consumption and 70% of global GHG emissions are related to urban energy technologies (Klemm and Wiese 2022). In the context of fossil fuel scarcity, the sustained utilization of finite fossil fuel supplies has shifted emphasis to the world's future energy predicament (Hosseini et al. 2013a). The rapid deterioration of fossil fuel reserves may culminate in considerable energy supply disturbances which causes climate change. As non-renewable fossil fuels are burnt, significant volumes of

carbon dioxide, GHG, are released into the atmosphere. GHG absorbs warmth in the atmosphere, which contributes to climate change (ClientEarth 2022). The approaching depletion of fossil resources, expanding energy consumption, as well as the impending threat of climate change have emerged as humanity's greatest compelling challenges (Lu et al. 2021). Thus, the achievement of domestic and international climate neutrality standards, and hence the reduction of GHG emissions, is the foremost fundamental priority (Klemm and Wiese 2022). Considering these economic and environmental considerations, renewable and sustainable technologies are becoming increasingly widespread as the 26th United Nations Climate Change Conference of the Parties (COP26), which refers to Conference of the Parties, established an agreement on absolutely vital climate change priorities, particularly intensified actions to develop resilience to combat climate change (Oxford 2022). The main theme of the conference focused on achieving net zero total carbon production by the middle of the century and keeping global warming within a reasonable 1.5 degrees Celsius threshold. Restructuring the energy structure driven by fossil energy and energetically promoting alternative energy is critical to achieving desired goals (Sun and Huang 2021).

Urban areas are crucial in the global structural change to a decreased, long-term energy strategy (Yazdanie and Orehounig 2021). Following the first industrial revolution, which was primarily focused on the consumption of fossil fuels such as coal and coal gas, natural gas, and oil, urban areas have been constructed and established on the fundamental concept that energy demand could continue to expand (Rutherford and Coutard 2014). Urban systems, on the other hand, have significant challenges in providing the increased demand for energy resources (Xia et al. 2021), which would result in increased emissions of GHG and pollutants if renewable and sustainable technologies are not integrated (Alhamwi et al. 2017). Urban areas will require appropriate technologies to address such areas of concern (Inage and Uchino 2020) and approaches to create local, renewable, and sustainable energy policies as they become more involved in global measures to mitigate climate change (Yazdanie and Orehounig 2021). Municipal authorities all around the world are designing and adopting increasingly renewable and sustainable energy sources and technologies as well as consumption in this environment, considering sustainable urban growth is inextricably linked to energy consumption patterns (Change 2014) and urbanization (Zhong et al. 2020). Energy efficiency has emerged as one of the greatest fundamental and complicated components of reducing CO₂ emissions entering the environment (Spedaletti et al. 2021). Furthermore, the Paris Agreement acknowledges urban' including local governments' global role in addressing climate change as well as achieving global CO₂ emission limitations (UNFCCC 2022). Thereby, local governments have

compelling motives to encourage energy planning techniques that are environmentally friendly (California Energy Commission 2005).

As evidenced by the vast and diverse body of research covered beforehand, urban energy consumption is developing in prominence, and models of urban energy systems are essential in determining improved designs, innovative policies, as well as accompanying technology (Keirstead et al. 2012). Designing and planning technologies for urban energy systems are tools that allow for quantitative, system-level evaluations to assist in the construction and decision-making of local energy policies (Yazdanie and Orehounig 2021). This approach comprises a wide range of problems, as well as various and contradictory assessments (Change 2014). Thus, the main objective of this paper is to reveal the roadblocks behind the structural change into renewable and sustainable energy technologies in urban areas. In accordance with these objectives, the following Research Questions (RQs) are generated to conduct this research,

- RQ1: What are the roadblocks to renewable and sustainable urban energy technologies which also influence climate change?
- RQ2: What is the interaction between the identified roadblocks?
- RQ3: What is the classification of the identified roadblocks?

To answer the RQs, this study is structured threefold: Initially, the roadblocks encountered in urban areas on the way to renewable and sustainable energy technologies were determined as a result of a Mini-systematic literature review (Mini-SLR). Then, the roadblocks were analyzed by adopting Total Interpretive Structural Modeling (TISM). In the third part of this study, the roadblocks are classified by using MICMAC Analysis. The novel contributions of the research can be stated as identifying the roadblocks to structural change of urban energy technologies to be renewable and sustainable, demonstrating the impact of the identified roadblocks, classifying the roadblocks - driving, linkage, dependent, and autonomous for urban energy technologies transition to renewable and sustainable energy technologies to combat climate change.

The remainder of this paper is as follows; the renewable and sustainable urban energy technologies is explained in Section 2. In Section 3, the research design is demonstrated including the explanation of adopted methodologies in detail. Numerical findings are presented in Section 4. Next, in Section 5, a discussion of the findings is presented including implications. Finally, the research is concluded in Section 6.

2. Renewable and Sustainable Urban Energy Technologies

Urban areas represent a vitally critical area of concern in the setting of sustainable development, the developing necessity of decentralized generating technologies based on renewable and sustainable energy sources to supply the expanding demand for energy technologies (Change 2014). Common goals for urban energy technologies include lowering energy supply expenditures, avoiding the use of fossil fuels, as well as increasing local value addition (Klemm and Wiese 2022). As cities expand, so does the energy demand. Urban areas, which correspond to 65% of total energy consumption and 70% of generated carbon pollution, are also critical to the globe's structural change to a low-carbon economy (IRENA 2022). Urban energy utilization and its environmental consequences, such as vast amounts of energy-related carbon emissions and water usage, impose substantial strain on sustainable development (Chen et al. 2021) which increases climate change. Urban areas are essential to the structural change of renewable and sustainable energy technologies (Alhamwi et al. 2017). The need for a full structural change from fossil fuels to renewable and sustainable energy technologies, and clean energy is growing more urgent (UN 2022) to combat climate change.

The threat of accelerated climate change has shifted the world's energy focus to renewable and sustainable energies (Hosseini et al. 2013b) since 75% of global energy consumption and 70% of global GHG emissions are related to urban energy systems (Klemm and Wiese 2022). Renewable and sustainable energy technologies may provide enormous advantages to urban areas, such as a healthier climate, updated services, and enhanced living areas (IRENA 2022). Renewable and sustainable energy are generated from supplies that potentially sustain ongoing processes while not endangering forthcoming populations' power requirements or ecology (Gawusu et al. 2022). Renewable energy is generated from organically renewing sources such as crops and biomaterials. It is plentiful, also can be utilized continuously, and therefore is greener, unlike fossil resources. Wind energy, solar energy, and hydropower are examples of renewable sources of energy since these possess a reduced influence on the environment, are commonly accessible, and are organically regenerated (Gawusu et al. 2022). Moreover, sustainable energy is generated from non-renewable sources such as solar and wind power, which cannot run out (Routledge 2022). The biggest widespread sustainable generating resources, such as wind, solar, and hydropower, are renewable technologies as well. Renewable energy technologies, clean energy technologies, and green energy technologies that contribute to the sustainable development goals, including such solar energy derived by solar panels, hybrid cars, carbon capture, utilization, and shortage (CCUS) are examples of sustainable energy technologies. Renewable and sustainable energy technologies comprise renewable energy forms as well as technology that boost energy

efficiency. Renewable and sustainable energy technology might generate 65 percent of the world's energy generation by 2030. It may potentially reduce carbon emissions by 90 percent of the energy industry by 2050, significantly reducing carbon emissions and therefore aiding in combating climate change (UN 2022). Previous related published works are tabulated in Table 1.

[Table 1 about here]

3. Research Design

3.1. Identification of Roadblocks to Renewable and Sustainable Urban Energy Technologies

In this section, the roadblocks to renewable and sustainable energy technologies are briefly explained by applying a Mini-SLR. The topics which are selected based on RQs are urban, energy technolog* and sustainab* and renewable, roadblocks. This step of the research design answers RQ1. Furthermore, the interrelationship of all three topics will be investigated employing search strings developed by grouping terms with the guidance of the connectors "AND" as well as "OR" as demonstrated below.

String = {"urban" AND "energy technolog" AND "sustainab*" AND "barrier" OR "challenge" OR "obstacle" OR "hindrance" OR "roadblock" AND "renewable"}*

The most relevant publications for examination in this research were determined after a thorough assessment and analysis of the existing literature. The steps of Mini-SLR are 1.Set search strings; 2. Select databases and search strings; 3.Monitor title, abstract and keywords; 4.diagonal reading; 5.full paper reading; 6.extraction of roadblocks and drivers. Secondly, relevant publications were gathered utilizing Web of Science (WoS) and Scopus. The purpose is to utilize search strings in the titles, abstracts, as well as keywords at first. The primary search generated 82 matches. The collected publications were evaluated in case of the inclusion criteria to confirm that they were published in English and had been peer-reviewed to guarantee strong and proven knowledge. The relevancy of the remaining 65 articles was additionally examined after the duplicates were removed from the collected data.

Table 1: Previous relate published work

Year	Authors	Country	Used method	Key contributions	Gaps
2023	Yadav et al.		VRIO Framework	<ul style="list-style-type: none">• A resource-based view for proactively administering organizations' tangible and intangible assets focused on lean and green concepts, with the purpose of investigating the roles of digital technologies in reaching net zero emissions and the sustainable development goals.	<ul style="list-style-type: none">• The strategies put in place to achieve net zero emissions by 2050 are untested.• Although lean and green techniques may have an impact on sustainability, the precise structure of the links among such ideas is unknown.
2023	Ghasemian Sahebi et al.	Iran	FISM-FDEMATEL integrated methodology	<ul style="list-style-type: none">• An assessment of the roadblocks to sustainable growth in the renewable energy supply chain.	<ul style="list-style-type: none">• To accomplish sustainable development and improve energy protection, considerable research activities in the renewable energy supply chain have not been done among various countries.
2022	Virmani et al.	Indian	Graph theory matrix approach (GTMA), Fuzzy-SWARA, Fuzzy-WASPAS	<ul style="list-style-type: none">• Analyze and illustrate the roadblocks to circular economy implementation in Indian micro, small, and medium-sized firms, followed by develop and determine alternatives to these roadblocks.	<ul style="list-style-type: none">• There is few research on micro, small, and medium-sized businesses.
2022	Shah and Longsheng	Pakistan	Integrated fuzzy-grey decision approach	<ul style="list-style-type: none">• Review of renewable energy alternatives observed in Pakistan.• Assessing the extent to how each roadblock affects each renewable energy option.	<ul style="list-style-type: none">• Analysis of the effect of each obstacle on each renewable and sustainable energy growth option to determine which renewable energy alternative has less impediments to

2022	Rodrigues and Seixas		Review	<ul style="list-style-type: none"> • Some critical facts concerning the impediments to the adoption of more secure design in the deployment of battery-electric buses in a worldwide setting for public transportation was examined. 	<p>ensure the attention may be shifted appropriately.</p> <ul style="list-style-type: none"> • There were no studies that covered all three sustainability components at the same time, since they were primarily concerned with operational, economic, and technical difficulties.
2022	Patel et al.		Conceptual	<ul style="list-style-type: none"> • A conceptual model that may be utilized to establish a sustainable supply chain using electric cars that addresses both ecological and social needs. • Interrelationships between the many factors being researched, embraced, and applied are offered. 	<ul style="list-style-type: none"> • There is an obvious shortage for study on multiple facets of the three main elements that will have an important effect on the growth of smart urban areas in the coming years; these elements are a sustainable supply chain, electric vehicles, and renewable energy sources.
2021	Kalpande and Toke	Indian	Review and Questionnaire	<ul style="list-style-type: none"> • Determines the current state of green supply chain management in the manufacturing industry. • Specifies and evaluates the variables associated with green supply chain management practices, performance, pressures, and hurdles. 	<ul style="list-style-type: none"> • Because of inadequate waste management rules and a shortage of recycling infrastructure in emerging nations like as China and India, investment recovery has gotten far less focus than in industrialized countries such as the United States and Germany.
2021	Jelti et al.		Review	<ul style="list-style-type: none"> • Emphasize the importance of the supply chain in the renewable energy production sector. • A full analysis of the supply chain's role to the renewable energy sector is provided, demonstrating the numerous roadblocks to 	

2021	Gawusu et al.		Review	<p>further growth, and recommending critical actions to address these roadblocks.</p> <ul style="list-style-type: none"> • Research is highlighted that are required to increase productivity and eliminate impediments to the growth of renewable energy green supply chain management. • There is presently no model that integrates distributed energy systems with green supply chain management techniques for effortless application by businesses. The challenges in designing and optimizing the supply chain are profoundly mirrored in the ambiguities and insufficient data on renewable energy as a sustainable source of energy.
2019	Ouedraogo	Africa	Review	<ul style="list-style-type: none"> • The following tendencies emerged from thematic analysis of the literature: Several reasons have hampered renewable energy's development in the region. • Despite acknowledgment of the advantages of renewable energy for Africa's sustainable development, the majority of governments have not gathered the required quantity of investment, nor have they made a significant legislative promise to the development of renewable energy supplies.
2019	Nevzorova and Kutcherov		Review	<ul style="list-style-type: none"> • An examination of the present impediments to the widespread use of biogas as an alternative form of energy, summarized by nation and classified into two basic groups: economies, both developed and developing. • There has been no recent, thorough examination of the challenges to widespread biogas adoption.
2019	Meijer et al.	Dutch	Review and Case Study	<ul style="list-style-type: none"> • Addresses hurdles and drivers for small and medium enterprises to commercialize sustainable energy innovations. • Although prior study has looked at the commercialization of technologies by small and midsize enterprises more study is needed, particularly in the field of renewable energy.

2018	Mittal et al.	India	Review	<ul style="list-style-type: none"> • This research compares the constraints to small-scale biogas technology dissemination in rural regions to the challenges to large-scale biogas technology dissemination in urban India. 	<ul style="list-style-type: none"> • None of this research investigated the obstacles that exist in different biogas systems operating at different sizes.
2018	Mangla et al.	India	Integrated Interpretive Structural Modelling and MICMAC	<ul style="list-style-type: none"> • Outlines and analyzes important impediments to circular supply chain management adoption. • This study presents a benchmarking framework to support executives and government authorities in developing key strategies for successfully addressing the difficult issues associated with circular models in the industrial setting. 	<ul style="list-style-type: none"> • There has been little research into the obstacles of adopting circular supply chain in emerging countries.
2018	Fernando et al.	Malaysia	Smart Partial Least Squares in Structural Equation Modelling	<ul style="list-style-type: none"> • The creation of a novel theoretical framework that connects energy management strategies to renewable energy supply networks. 	<ul style="list-style-type: none"> • Due to a lack of understanding about energy efficiency, businesses challenge to control energy properly, limiting potential such as transforming waste into energy to support corporate goals.
2018	Dominković et al.	European Union	Review	<ul style="list-style-type: none"> • This article takes a holistic approach, concentrating on the relationships among different energy sectors and examining the roadblocks and potential of the alternatives for quicker penetration of the energy system. 	<ul style="list-style-type: none"> • There has been an absence of thorough study that has taken into consideration the interplay between diverse modes of transportation and the entire increased energy consumption for the greener options.
2017	Elum and Momodu	Nigeria	discourse analysis	<ul style="list-style-type: none"> • Defining societal and political roadblocks as the main major impediments to the 	<ul style="list-style-type: none"> • There is a requirement to include more renewable energy alternatives into

2015	Luthra et al.	Indian	Analytical Hierarchy Process	<p>quick adoption of a green economy using renewable energy for long-term growth.</p> <ul style="list-style-type: none"> • Determines the numerous roadblocks to the implementation of renewable or sustainable energy technology in India. • Classifies highlighted hurdles to the development of renewable or sustainable energy solutions. 	<p>agricultural and urban energy schemes, such as hydro, solar, biogas, and wind.</p> <ul style="list-style-type: none"> • It emphasizes the shortage of identifying key impediments to the implementation of renewable and sustainable energy technology in the Indian context.
2015	Li et al.	Taiwan	Case Study	<ul style="list-style-type: none"> • The function of green supply chains in eco-industrial parks in contributing to a green economy was studied in this study. • The green economy solutions and appropriate methods for assessment were presented by examining the hurdles from the perspectives of institutions, regulation, technology, and finance. 	<ul style="list-style-type: none"> • Therefore, there is an urgent need to develop and implement the green technologies into the existing facilities, especially in the developing countries
2015	Fernando and Yahya	Malaysia	Qualitative	<ul style="list-style-type: none"> • Investigates the problems of implementing renewable energy planning and how enterprises dealt with low carbon issues in the supply chain. The findings of this article are anticipated to serve as the foundation for the idea creation of a renewable energy supply chain. 	<ul style="list-style-type: none"> • To progress the area, a clear grasp of the renewable energy idea, as well as the internal and external constraints that influence renewable energy supply chain application, is required.
2015	Ahmad and Thar	Malaysia	Analytical Hierarchy Process	<ul style="list-style-type: none"> • The feasibility of various renewable resources is examined. • A mechanism for ranking renewable solutions is designed. 	

A number of 51 publications were reviewed in their entirety after passing the preliminary assessment. Publications that did not correspond with the article's objective were sorted immediately. In the end, 40 articles were found to be suitable for the investigation and then were kept for further investigation. The extracted roadblocks are demonstrated in Table 2.

Table 2: Roadblocks to Renewable and Sustainable Urban Energy Technologies

Roadblocks	Definition	References
(B1) High initial investment cost	The majority of renewable and sustainable energy technologies have a high initial investment cost, such as the cost of constructing the plant, purchasing equipment, hiring technical personnel, the cost of execution, the excessive cost of managing and preserving biogas plants, and the cost of introducing technology.	Rodrigues and Seixas (2022); Nevzorova and Kutcherov (2019); Ghimire and Kim (2018); Mittal et al. (2018); Shukla et al. (2018); Mosannenzadeh et al. (2017); Bundhoo et al. (2016); Sherriff (2014); Yuan et al. (2013); Mirza et al. (2009); Schleich (2009); Adhikari et al. (2008); Painuly (2001)
(B2) Lack of subsidies and financial support programs	For project activities, there is insufficient external financial support as well as funding. Credit, capital, RandD funding, and cost disincentives are all limited for renewable and sustainable energy technologies.	Nevzorova and Kutcherov (2019); Shukla et al. (2018); Ghimire and Kim (2018); Mosannenzadeh et al. (2017); Sen and Ganguly (2017); Luthra et al. (2014); Sherriff (2014); Dulal et al. (2013); Javadi et al. (2013); Nepal (2012); Kahraman et al. (2009); Schleich (2009); Adhikari et al. (2008); Painuly (2001); Banister (1998)
(B3) Absence of coherent related policies	Ecosystem and biodiversity degradation due to a lack of a consistent renewable energy policy as well as supportive environmental regulations and legislation renewable and sustainable energy technologies.	Rodrigues and Seixas (2022); Maurya et al. (2021); Gao et al. (2019); Nevzorova and Kutcherov (2019); Ghimire and Kim (2018); Shukla et al. (2018); Mosannenzadeh et al. (2017); Sen and Ganguly (2017); Luthra et al. (2015); Darmani et al. (2014); Zhang and Wang (2013); Gurung et al. (2012); Surendra et al. (2011); Mirza et al. (2009); Riebesell et al. (2007)
(B4) Insufficient infrastructure	Inadequate infrastructure and a lack of institutional capacity. The lack	Poudyal et al. (2019); Ghimire and Kim (2018); Shukla et al.

- of physical infrastructure, transfer, and distribution systems in potential renewable and sustainable energy supply areas mean that their potential is underutilized. (2018); Sen and Ganguly (2017); Spiess and De Sousa (2016); Sherriff (2014); Gurung et al. (2012); Yadoo and Cruickshank (2012); Nepal (2012); Sovacool et al. (2011); Mirza et al. (2009); Adhikari et al. (2008)
- (B5) Lack of coordination among authorities** Bureaucracy is at an all-time high. Authorization procedures for project operations are lengthy and complicated. Lack of coordination and cooperation within and between multiple ministries, agencies, institutes, and other stakeholders slows and inhibits the development and commercialization of renewable and sustainable energy technologies. Nevzorova and Kutcherov (2019); Ghimire and Kim (2018); Mosannenzadeh et al. (2017); Bhattacharya and Jana (2009); Mirza et al. (2009)
- (B6) Lack of information** There is a scarcity of high-quality, trustworthy data and information about renewable and sustainable energy technologies, which discourages further investment in these technologies. Rodrigues and Seixas (2022); Nevzorova and Kutcherov (2019); Ghimire and Kim (2018); Shukla et al. (2018); Sen and Ganguly (2017); Bhattacharya and Jana (2009); Mirza et al. (2009); Schleich (2009)
- (B7) Lack of skilled and trained personnel** Renewable and sustainable energy technologies penetration is limited by a lack of skilled employees for training, demonstration, maintenance, and operations, as well as insufficient awareness and communication initiatives for technological diffusion. Ghimire and Kim (2018); Shukla et al. (2018); Mosannenzadeh et al. (2017); Sen and Ganguly (2017); Darmani et al. (2014); Dulal et al. (2013); Yadoo and Cruickshank (2012); Amer and Daim (2011); Kahraman et al. (2009); Brown (2001); Painuly (2001); Banister (1998)
- (B8) Competition with non-renewable technologies** Due to the monopolistic character of the non-renewable energy sector, competition has been disrupted for renewable and sustainable energy technologies. Nevzorova and Kutcherov (2019); Sen and Ganguly (2017); Spiess and De Sousa (2016); Painuly (2001); Eyre (1998)

(B9) Limited awareness and consumer interest	Due to a lack of familiarity and awareness with renewable and sustainable energy technologies, a high-risk perception, and ambiguities regarding resource evaluation, there are impediments to securing competitive forms of finance for their development.	Nevzorova and Kutcherov (2019); Ghimire and Kim (2018); Mosannenzadeh et al. (2017); Sen and Ganguly (2017); Luthra et al. (2015); Sherriff (2014); Dulal et al. (2013); Gurung et al. (2012); Yadoo and Cruickshank (2012); Surendra et al. (2011); Mirza et al. (2009); Rohdin and Thollander (2006); Song (2006); Painuly (2001)
(B10) Lack of standardized renewable and sustainable energy technologies	Due to restricted local manufacture of specialized equipment, new projects and innovations have a low acceptance rate. There is also a scarcity of capacity in renewable and sustainable energy technologies and RandD facilities.	Ghimire and Kim (2018); Shukla et al. (2018); Mosannenzadeh et al. (2017); Luthra et al. (2014); Sherriff (2014); Yuan et al. (2013); Mirza et al. (2009); Painuly (2001)

3.2. Total Interpretive Structural Modeling (TISM)

TISM is a significant tool for strengthening consensus viewpoints in a variety of scenarios and identifying roadblocks to renewable and sustainable urban energy technologies to combat climate change. This step of the research design answers RQ2. It is a method for addressing three basic concerns about theory construction: "what" by displaying nodes as possible factors, "why" and "how" by displaying interconnections (Kayikci et al. 2021; Sushil 2021). There are nine steps to such a method, which are clearly explained as follows:

Step 1- Identify and define roadblocks: Identification of the roadblocks is accomplished by the use of current literature in Section 3.1. as Jena et al. (2017) suggested. A list of 10 roadblocks to renewable and sustainable urban energy technologies is developed in the first step of the research design of this research.

Step 2 – Establish the contextual relationships between the roadblocks: The contextual relationship between the roadblocks must be specified (Jena et al. 2017). With the guidance of discussions with experts throughout the setting of logical reasoning, explanations of the interaction between roadblocks are gathered in a knowledge base matrix. Thus, expert opinions establish contextual interconnections between the roadblocks, including factor B1 will contribute to achieving factor B2, and so on, with an explanation for each roadblock.

Step 3 - Relationships are interpreted in binary terms: This is the first step in the TISM, which is supposed to describe the standard ISM in greater detail. As a result, in TISM, the meaning

of a relationship is defined by evaluating how one roadblock can influence or strengthen another. In a pair-wise comparison, each roadblock is matched to one another separately.

Step 4 –Reachability matrix and transitivity check: When B_x affects B_y and B_y affects B_z , the transitivity rule appears to apply, consequently, B_x influences B_z (Kayikci et al. 2021; Mathivathanan et al. 2021; Dubey et al. 2015; Jayalakshmi et al. 2015). After new transitivity, the logic knowledge base is modified (Sushil 2021). The total number of pair-wise comparisons for n predefined roadblocks is $n*(n-1)$ as there are two conceivable directional relationships, $i-j$ as well as $j-i$. Subsequently, in the knowledge base, " $n*(n-1)$ " rows are constructed for assessment.

Step 5 – Level partition: Following the completion of the final reachability matrix, the following step is level partitioning, which involves arranging the roadblocks into ranking levels based on their influence on other roadblocks (Shibin et al. 2017). Beginning with level I, the levels are established. The roadblocks at the level I are not connected to the roadblocks below them (Mathivathanan et al. 2021; Mathiyazhagan et al. 2013). When the interaction set and the reachability set are the same, the roadblock is classified as level I. The set is then changed by removing the roadblock that was associated with a level. This procedure is repeated until all roadblocks have been assigned a level.

Step 6 – Interaction Matrix: To generate the interaction matrix, logical reasons are inserted rather than binary values of 1. Only the relationships that are considered effective relationships and possess a substantial association are included in this matrix (Mathivathanan et al. 2021; Dubey et al. 2015; Jayalakshmi et al. 2015).

Step 7 – Interpretation Matrix: The logical reasoning of each positive association is inserted into each corresponding cell on the interaction matrix in this step, and the output is an interpretation matrix. In this research, data from logic knowledge is utilized to construct a ten-by-ten interpretive matrix.

Step 8 – TISM model: Depending on the level determined in the preceding step, the diagraph is constructed. Starting at the level I and progressing to level IV, every roadblock is set at the top to the bottom of the diagraph. Based on the final reachability matrix, arrows are used to represent the connections between the roadblocks. Transitivity links are depicted by dashed arcs, whereas direct links are shown by solid arcs. By putting the logical reasoning on the corresponding arcs, the diagraph can be found.

Step 9 – Validation: Experts analyzed 90 pair-wise comparisons comprised of $10 * 9$ roadblocks at the start of this assessment. A total of 42 relevant associations were discovered as a consequence of this evaluation. The model structure must be validated in terms of

roadblocks and interactions between roadblocks (Sushil 2021). This procedure is performed by supplying responses to Sushil (2012)'s proposed questions by considering all roadblocks and relationships with the assistance of experts in a group setting, (1) Have all relevant roadblocks been considered? (2) Is the relationship interpretation accurate? (3) Are the interpreting paths accurate?

3.3. MICMAC Analysis

The MICMAC is acknowledged as cross-impact matrix multiplication applied to classification (Mathivathanan et al. 2021). This step of the research design answers RQ3. The roadblocks are classified using MICMAC analysis depending on their dependence as well as driving powers. The MICMAC investigates the impact of roadblocks as measured by relationships (Mathivathanan et al. 2021). Thus, the roadblocks are classified as driving, linkage, dependent, and autonomous.

4. Numerical Findings

The roadblocks are identified as explained in detail in Section 3.1. to answer RQ1. In this section, the TISM methodology is applied with the opinions of six experts from the energy industry. As mentioned in the second step of TISM, the experts filled out a form to analyze the contextual relationships of the roadblocks. Each expert has at least three years of experience in the energy sector. The experts were asked to produce a pair-wise contextual relationship between all roadblocks in order to create the interpretive logic knowledge base. Because ten roadblocks were addressed in total in this study, the experts evaluated a total of 90 (10×9) potential interconnections. Next, a pair-wise comparison matrix in terms of ten-by-ten matrixes was generated. This transformation produces the initial reachability matrix: V (factor i will help to achieve/alleviate factor j), A (factor j will help to achieve/alleviate factor i), X (factors i and j will help to achieve/alleviate each other) and O (factors i and j are unrelated). In the notion of the third step of TISM, the value "1" or "0" is assigned based on the interconnection between roadblock B_i and roadblock B_j for each (i, j) th cell (Sushil 2021). Table 3 illustrates solely the direct interconnections in the initial reachability matrix.

Table 3: Initial reachability matrix

	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
B1	1	0	1	1	0	0	1	0	0	<u>1</u>
B2	0	0	1	0	0	0	1	1	<u>1</u>	1
B3	1	0	1	0	0	0	0	<u>1</u>	1	1
B4	0	0	1	0	1	1	<u>1</u>	0	0	0
B5	0	0	1	0	0	<u>1</u>	0	0	0	0
B6	1	0	0	0	<u>1</u>	0	0	0	0	0
B7	1	0	0	<u>1</u>	1	1	1	0	0	0
B8	0	0	<u>1</u>	0	0	0	1	0	0	0
B9	1	<u>1</u>	1	1	0	1	0	0	0	0
B10	<u>1</u>	1	1	0	1	0	1	0	0	0

The transitive connections generated following the implementation of the transitivity rule are presented in Table 4 with orange highlighting after constructing the original reachability matrix (step 3). In step 4, expert opinions are employed to verify each transitive relationship. Only the most effective links are selected for the investigation after the revision. The final reachability map is generated at the completion of this stage, as depicted in Table 3.

Table 4: Final reachability matrix

	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	Driving Power
B1	1	1	1	1	0	0	1	0	0	<u>1</u>	6
B2	1	0	1	0	0	1	1	1	<u>1</u>	1	5
B3	1	1	1	0	0	0	0	<u>1</u>	1	1	4
B4	1	0	1	0	1	1	<u>1</u>	0	0	0	6
B5	0	0	1	0	0	<u>1</u>	1	0	0	0	4
B6	1	0	1	0	<u>1</u>	0	1	0	0	0	3
B7	1	1	0	<u>1</u>	1	1	1	0	0	0	5
B8	0	0	<u>1</u>	0	1	1	1	0	0	0	6
B9	1	<u>1</u>	1	1	0	1	0	0	0	0	7
B10	<u>1</u>	1	1	1	1	0	1	0	0	0	6
Dependence	8	5	9	4	5	6	8	2	2	3	

In step 5, level partitioning is accomplished by categorizing the roadblocks into hierarchy levels based on how each roadblock affects the other roadblocks (Shibin et al. 2017). Furthermore, as demonstrated in Table 5, the reachability set, the antecedent set, and the intersection set are all established by originating from the final reachability matrix.

Table 5: Level partition

Roadblock	Reachability Set	Antecedent Set	Intersection Set	Level
B1	B1	B1, B2, B3	B1	III
B2	B2, B3	B2, B3	B2, B3	IV
B3	B2, B3	B2, B3	B2, B3	IV
B4	B4, B5, B6, B8, B10	B1, B2, B4, B5, B6, B7, B8, B10	B4, B5, B6, B8, B10	I
B5	B4, B5, B8	B2, B4, B5, B7, B8, B9	B4, B5, B8	I
B6	B4, B6, B8, B10	B4, B6, B7, B8, B10	B4, B6, B8, B10	I
B7	B7, B9, B10	B1, B7, B9, B10	B7, B9, B10	II
B8	B4, B5, B6, B8	B1, B2, B3, B4, B5, B6, B8, B9, B10	B4, B5, B6, B8	I
B9	B7, B9, B10	B1, B3, B7, B9, B10	B7, B9, B10	II
B10	B7, B9, B10	B1, B2, B3, B7, B9, B10	B7, B9, B10	II

As shown in Table 6, an interpretive matrix is created by introducing information from the logic knowledge base.

[Table 6 about here]

In the Table 6, Renewable and sustainable energy technologies are mentioned as RSET. The ultimate step of the TISM, validation of the TISM model, is considered necessary for the study results reliability assessment following the final matrix is determined. In this sense, for the validation evaluation process, a supplementary questionnaire that included the final matrix's interactions, as well as the logical reasoning for every positive connection, was provided and shared with a further ten experts who were not part of the preceding data set, a diverse group comprised of academics as well as industry professionals. In this case, every expert has questioned the exact inquiry including all linked roadblocks. The average scoring of each connection was generated based on the data acquired from the experts, and that was determined to allow or reject such positive relationships based on the threshold value of less than 3,00. All forty-two interactions or relationships have been significant based on the computations of the expert answers. As a result, after validation, the TISM model remained unchanged since there are numerous links/interactions to show in one figure in the TISM model, two figures are constructed for direct and indirect links/interactions. To answer RQ2, the TISM model with direct links is shown in Figure 1, whereas the model with indirect links is shown in Figure 2.

[Figure 1 about here]

[Figure 2 about here]

Table 6: Interpretive matrix

	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
B1	Standardized RSET is lacking due to high initial investment cost	High investment RSET cost is a limiting factor in awareness	RSET high investment cost	Personnel is a direct investment cost	0	0	Insufficient infrastructure is a result of excessive cost due to reoccurring long term maintenance cost of RSET	0	0	<u>1</u>
B2	Lack of subsidies will make standardization of RSET more costly	0	Subsidies are vital for small enterprises to enter the market and compete	0	0	Lack of subsidies affect lack of coordination via insufficient infrastructure	Lack of financial support programs cause the infrastructure to be insufficient	Subsidies is a policy to attract investors for RSET	<u>1</u>	Higher subsidies lead to lower cost or the way other meanwhile RSET relies on subsidies investment attractive Unfavorable policy leads to higher costs for both industry and consumers
B3	Policies have an enabler effect on RSET standardization	Policy affects RSET and RSET affects awareness	Consistent policy allows increased competition	0	0	0	0	<u>1</u>	Financial support is dictated by the policies	
B4	In-sufficient infrastructure creates unique RSET requirements	0	Insufficient infrastructure allows opportunities for competition	0	Insufficient infrastructure creates lack of data for improvement	Insufficient infrastructure causes lack of coordination	<u>1</u>	0	0	0

B5	0	0	Lack of coordination creates unregulated competition	0	0	<u>1</u>	Lack of coordination delays infrastructure development	0	0	0
B6	Lack of data makes RSET standardization difficult	0	Lack of access to information leads to slower competition	0	<u>1</u>	0	Lack of information delays infrastructure planning	0	0	0
B7	Lack of skill and training limits the implementation	Lack of skill/training for RSET contributes to lower awareness	0	<u>1</u>	Lack of skilled/trained personnel causes inaccurate quality	Lack of skill/training creates confusion among authorities	Lack of skill/training leads to poor infrastructure	0	0	0
B8	0	0	<u>1</u>	0	Competition increases access to information	Lack of competition leads to negative business practices such corruption	Competition affects insufficiency of the infrastructure	0	0	0
B9	Limited awareness decreases pressure of standardization	<u>1</u>	Limited consumer interest stagnates competition	Lack of awareness diminishes interest in RSET jobs	0	Lack of consumer interest leads to shifting priorities of authorities	0	0	0	0
B10	<u>1</u>	Lack of RSET standardization creates confusion in interest	Lack of RSET will decrease competition	Lack of standardized RSET increases training cost	Lack of standardization increases irrelevant data	0	Lack of standardization decreases quality of infrastructure	0	0	0

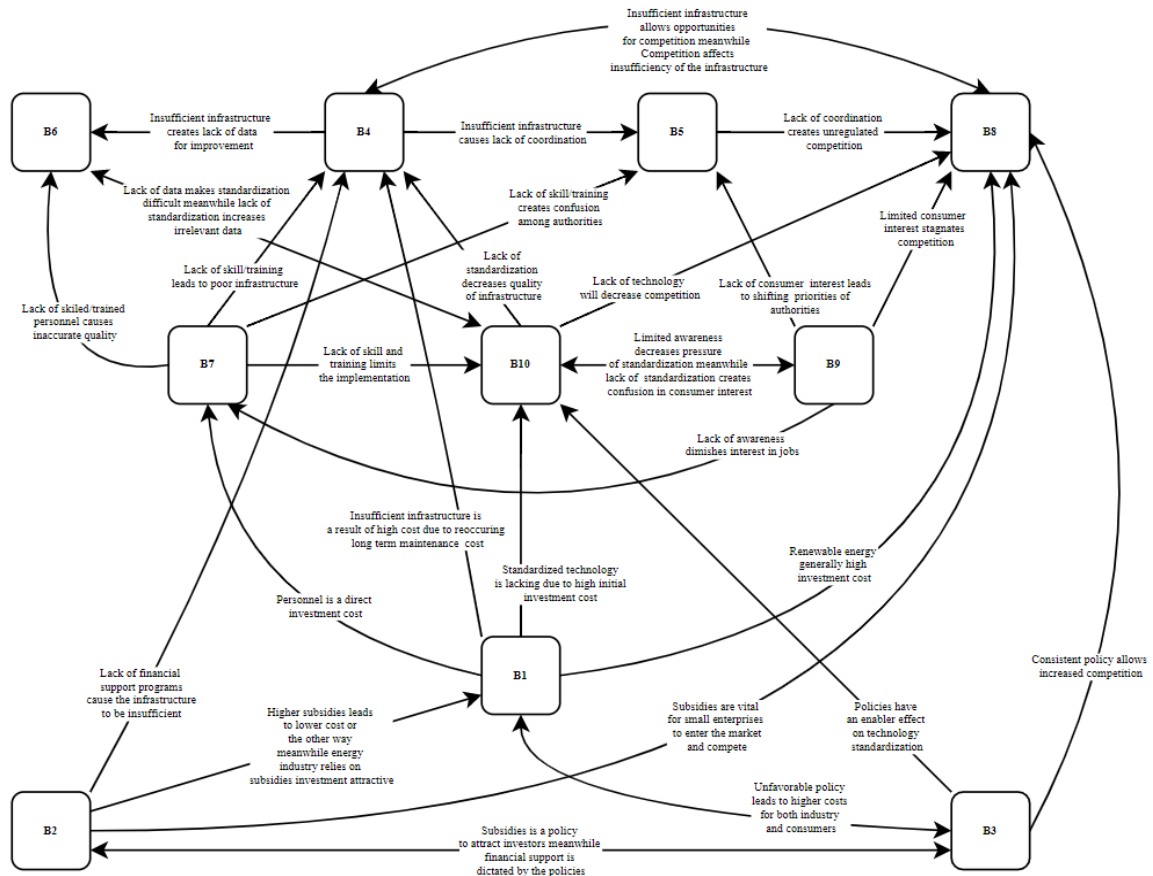


Figure 1: TISM Model with direct links

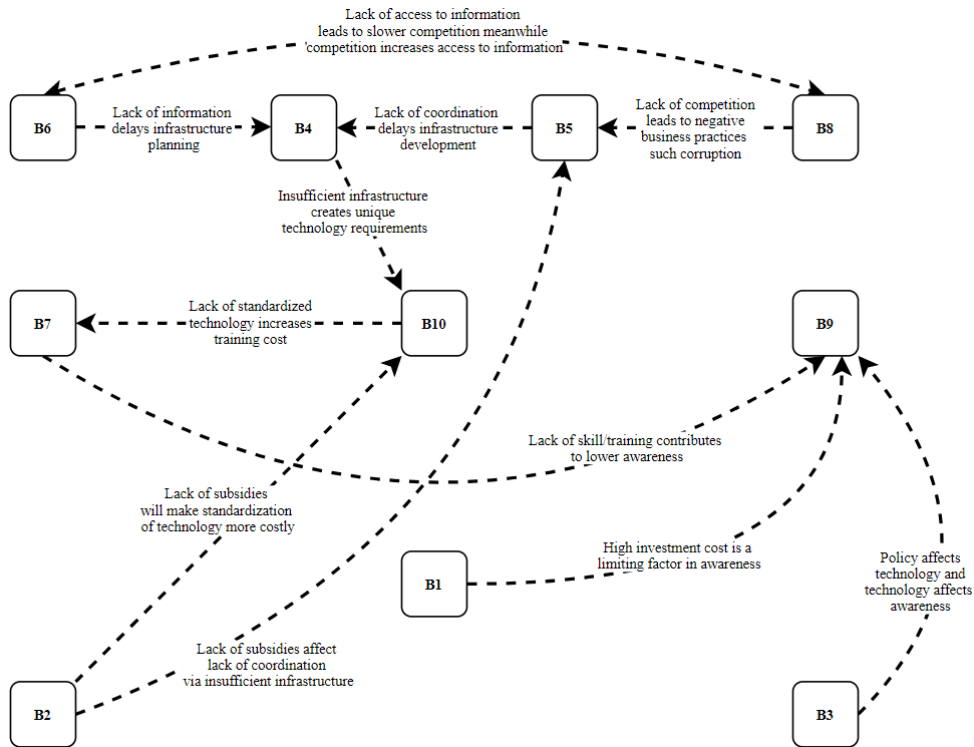


Figure 2: TISM Model with indirect links

For MICMAC, the final reachability matrix is used to determine dependence and driving powers for each roadblock. The driving powers represent the y-axis, whereas the dependent values constitute the x-axis. Figure 3 demonstrates the MICMAC diagram.

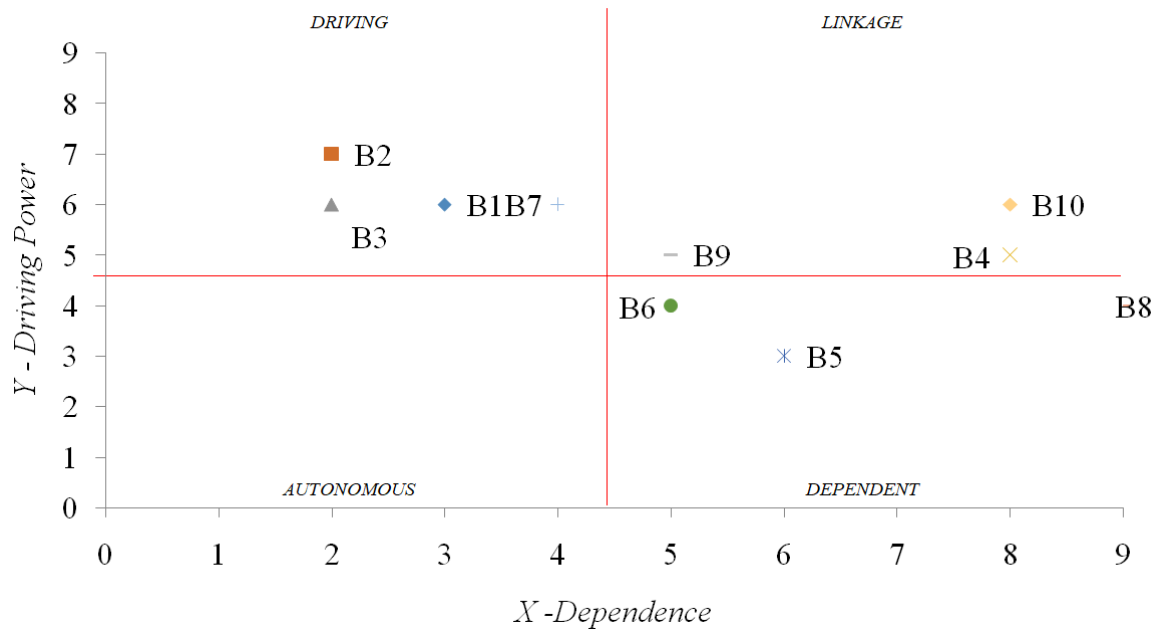


Figure 3: MICMAC diagram

As the answer for RQ3, the roadblocks are shown in four quadrants: driving, linkage, autonomous and dependent. None of the roadblocks are classified as autonomous, implying that they have limited driving and dependency abilities. B5, B6, and B8 are the dependent roadblocks. Furthermore, linking roadblocks have significant dependence and driving powers, with B4, B9, and B10. Finally, the driving roadblocks B1, B2, B3, and B7 have strong driving power but are not dependent.

5. Discussion

This chapter of the paper of the study outlines the inquiry of the roadblocks to renewable and sustainable urban energy technology. In this case, available literature was reviewed to determine roadblocks from both an urban energy and renewable and sustainable technologies perspective. Afterwards structured questionnaires were administered to the group of experts for employing the TISM approach and the MICMAC analysis, construct a connection among these roadblocks, the transitive relations as well as analyze the causal interactions. After

implementation of the questionnaire, analyses were made to propose a framework that can assist companies to acknowledge the roadblocks to renewable and sustainable urban energy technologies.

TISM approach has been applied in the literature for several reasons such as green supply chain management enablers (Dubey et al. 2015), enabler and roadblock evaluation for green supply chain management (Shibin et al. 2016), enabler analysis for circular initiatives in supply chains (Khan et al. 2020). The main contribution of this study is to provide a roadmap for the roadblocks to renewable and sustainable urban energy technologies. Thus, the findings show that all roadblocks are necessary for renewable and sustainable urban energy technologies. As seen in Figure 1 and Figure 2, the roadblocks at the level 1 are B4(Insufficient infrastructure), B5(Lack of coordination among authorities), B6(Lack of quality and reliable data and information), B8(Competition with non-renewable technologies); roadblocks in the level 2 are B7(Lack of skilled and trained personnel), B9(Limited public participation, awareness, and consumer interest), B10(Lack of standardized technology); roadblock in the level 3 is B1(High initial investment cost); and lastly, roadblocks in the level 4 are B2(Lack of subsidies and financial support programs) and B3(Absence of coherent related policies). Furthermore, as the result of MICMAC analysis, none of the aforementioned roadblocks are classified as autonomous variables, implying that they are all required. Driving roadblocks have a large influencing effect due to their high driving power and minimal reliance, which can be deducted (Chandramowli et al. 2011). They are unanticipated and difficult to manage since linking roadblocks are vulnerable to their actions. Driving roadblocks requires a considerable deal of effort to have a significant impact on the entire system.

As the results indicate, B1 and B2 are driving roadblocks as it is also stated by Nevzorova and Kutcherov (2019), excessive investment costs as well as a scarcity of subsidies, monetary support initiatives, and low-interest credit are key economic obstacles for emerging nations. Especially via long-term RandD (B2) can the cost of technologies (B1) be reduced, and practical concerns resolved as necessary (Ghimire and Kim 2018). B1 influences B7, hence the supply of skilled labor is dependent on government-supported training programs (Ghimire and Kim 2018). New infrastructure is required to educate employees and ensure that employees possess quick availability to spare materials (Sen and Ganguly 2017). Also, According to Ghimire and Kim (2018), political uncertainty (B3) may hinder national and international investors (B2) since considerable progress cannot be made without unambiguous political commitment and solid government encouragement. Moreover, another driving roadblock is B3, and policy instruments must be devised in a consistent manner to encourage the

development of renewable technology (Nevzorova and Kutcherov 2019). However, Poudyal et al. (2019) highlight the interaction between B3 and B4 which is not a result retrieved from our research, their research state that creating prospective comprehensive energy strategies and projecting the growth of power generation and distribution networks and various structures to satisfy needs and, most critically, to address the energy crisis. A lack of knowledge can be caused by a lack of instructional and guidance resources for the selection and economic viability assessment of renewable technology, which can result in a lack of awareness (B9) and a low level of knowledge (B6) (Nevzorova and Kutcherov 2019).

5.1. Implications

This research can provide a guideline for renewable and sustainable urban energy technologies by highlighting the significant roadblocks to combat climate change. In this perspective, the findings of this research demonstrate that the roadblocks B1 (High initial investment cost), B2 (Lack of subsidies and financial support programs), B3 (Absence of coherent related policies), and B7 (Lack of skilled and trained personnel) possess the strongest driving forces therefore are not dependent on any other roadblocks. As a result, concentrating solely on these roadblocks can make a considerable impact. Especially B1 (High initial investment cost) may also be a roadblock to SDG 7 (Affordable and clean energy) since the excessive cost is not considered as affordable and constitutes a roadblock to renewable and sustainable urban energy technologies. Considering this knowledge, it is necessary to concentrate on these roadblocks.

6. Conclusion

Urban areas are crucial to the global structural shift to a low-carbon, long-term energy infrastructure. The process of selecting which local energy systems to participate in, which energy efficiency techniques to promote, and which regulations to enact affecting renewable and sustainable urban energy technology is known as urban energy planning. The primary goal of this paper is to examine the roadblocks to urban renewable and sustainable energy transition for structural change in urban regions. A research design is made up of three sections: A Mini-SLR was conducted in order to uncover the key challenges that urban regions face in their transitioning to renewable and sustainable urban energy technologies. The interplay between the roadblocks and the origin of causation was then examined using TISM. The roadblocks are classified as driving, linkage, dependent, and autonomous based on their dependence and driving powers using MICMAC Analysis in the third part of this research. The primary findings

highlight that dependent roadblocks are defined as B5 (Lack of coordination among authorities), B6 (Lack of information), and B8 (Competition with non-renewable technologies). Moreover, linkage roadblocks have high dependence and driving powers which are B4 (Insufficient infrastructure), B9 (Limited awareness and consumer interest), and B10 (Lack of standardized technology). Lastly, B1 (High initial investment cost), B2 (Lack of subsidies and financial support programs), B3 (Absence of coherent related policies), and B7 (Lack of skilled and trained personnel) are the driving roadblocks with high driving power however not dependent.

Given the number of roadblocks found, the limitations of this research may be addressed; hence, the proposed next research can be specified as a full systematic literature review. The exploratory factor analysis may then be used with a larger number of specialists. Additionally, the drivers and their impact on roadblocks might be explored.

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Declarations

Ethics approval and consent to participate: All authors follow the ethics in the research and provide consent to participate in the research.

Consent for publication: All authors provide consent for publication.

Availability of data and material: All the data has been provided in manuscript

Competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding: No

Authors' contributions: **Yiğit Kazançoğlu:** Ideas, Conceptualisation, Writing- Original draft preparation, Data collection and curation, Methodology, Formal analysis

Nazlıcan Gozacan-Chase: Ideas, Writing- Original draft preparation, Conceptualisation, Formal analysis, Project administration

Sunil Luthra: Formal Analysis, Project administration, Supervision, Critical review, Commentary and revision

Anil Kumar: Formal Analysis, Supervision, Critical review, Commentary and revision

Acknowledgements: The authors would like to thank experts used in research.