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Enhancing Sustainability through Green IoT: An Empirical Analysis of Energy Efficiency Realization in the Smart Cities.

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Abstract

This paper examines the application of Green Internet of Things technologies to maximize energy efficiency optimization in smart cities. The research is based on a survey of 126 respondents from different age group. A stratified random sample was employed for this cross-sectional study. And, investigates the interaction of the factors that ensure the success of this optimization. We applied structural equation model to analyze the response of the 126 respondents where 3 independent variables, 1 mediating variable's impact was analyzed on the dependent variable "Smart City development" which shows impactful observations that changes according to other variables. Furthermore, the paper will focus on the different applications of energy realization in smart cities and how Green IoT has further enhanced the process. It will also look at the ways the integration of urban infrastructure and the use of renewable sources, including the policies by the government, has contributed to energy optimization. Both residents and businesses perceptions as well as those of city officials ADIES will be compared, aligned, and contrasted such that the study can highlight the critical challenges and opportunities in energy efficiency implementation in a smart city. The results will guide policymakers and other stakeholders in defining effective strategies to address Green IoT's potential in reducing energy consumption for a possible sustainable urban life.

Keywords: *Green IoT, Energy Efficiency, Smart Cities, Renewable Energy, Urban Infrastructure, Government Policy.*

1. Introduction

Green IoT is keen to revolutionize the quality of human life by providing efficient connection, wired or wireless sensors and many smarter city solutions. In this paper we have outlined the sustainability and goals that smart cities versioned. With IoT components and communication technologies the devices by IoT will give enormous applications of the real time monitoring just like this paper "Improving the security of wireless sensor networks in an IoT environmental monitoring system." by (Tellez 2016) has mentioned about environmental monitoring. IoT is able to gather a huge amount of data and also able to deliver it by using the advance technologies for communication. Smart cities apply the recent technologies to enhance the quality of life and growth of economy which is achieved through four different levels. The levels are real time data collection, analyze the data to use in further level, interpret the results for decision making and taking steps to improve the procedures. Urbanization is increasingly growing and within 2050 it is expected to reach 66% meaning 2.5 billion people will be adapting this(Kumar 2020). Smart city needs to use the real time data to deal with problems that is why installing IoT devices is crucial for efficiently

managing the nature because the devices are created in such a way that is able to learn by itself. Some widely usage of IoT devices are smart air quality monitor, smart waste management, smart parking, traffic monitoring, sensors and environmental monitoring (Humayun 2020; Zhang 2020; Shahid 2021).

The devices used in IoT are known to consume the energy and how to make use of the resources. A study by Shaikh FK, Zeandally S, Exposito E (2017) "Enabling technologies for green internet of things" revealed that energy consumption can be reduced through well planned energy transmission of data. Cities need to make new projects with latest technologies for managing the resources ok smart cities as the population is heavily growing inside the smart cites. Despite the privileges of smart city there also some barriers such as overcrowding, climate change. Optimal energy usage, managing resources falls under the energy optimization category and this is one of the major challenges that smart cities have to confront and in our paper we have discussed the energy efficiency realization in smart cities (Eckhoff 2017) (Jeong 2019, Trencher 2019).

2. Literature Review

IoT has been giving us huge opportunities for innovative solutions in interconnection, sensors, applications, edge computing and many more (Shahid, Ashraf et al. 2021). IoT also provide us with data collection & analysis (Jeong and Park 2019). And the collected data doubles every two years, and this might become 163 Zettabytes within 2025 (Ziakis and Vlachopoulou 2023). From a predictive and past record graph we could say this within 2025 the number of data will rise to 10 times than it was in 2016 (Dashkevych and Portnov 2022). The connection of IoT can be normally done in three ways such as people to people connection, machine to people and lastly machine to machine connection (Busulwa 2020). Also, there are studies that mentioned different features of IoT too(Tavakol and Dennick 2011) . A study conducted by Atzori, et al. mentioned that crucial technologies allow the advancement of IoT wireless and wired in both fields (Trencher 2019). Another study has mentioned that a cloud vision that brings under one roof the applications of IoT technology to provide services (Humayun, Alsaqer et al. 2022). The future of IP is the Internet Protocol version 6 as per them because it will allow for unique IP address identification (Lee, Whitehead et al. 2014).

The recent advancement of sensors cloud includes Alamri, Ansari et al. (2013) shows the future of sensor cloud in green IoT. A study by Shoup (2006) gives the data the fuel that is wasted is about 47,000 gasoline gallons that is equal to having 38trips around the world which contaminates the air by about 730 tons of Carbon Dioxide. This study by Geng and Cassandras (2013) shows how people could reserve a parking lot using the smart parking system which is depends on solving a mixed integer linear problem. Another work of Yang, Portilla et al. (2012) shows how drivers can know which spot is free for parking by wireless sensor network. A study by Ejaz et al. (2019) described how the technologies has been used in smart cities and the architecture & its applications. Also, this study shows a discussion on the application of various components of the IoT in smart and they are regularly reviewed with the ongoing smart city projects(Kumar, Banga et al. 2020).

As the population is rising some major problems are becoming prominent such as high cost, air pollution and this problem will occur if there any reduction of energy assets (Dashkevych and Portnov 2022). The future cities will have to go through this vital problem and then they will focus on smart and green cities (Nam and Pardo 2011). Smart cities are increasingly viewed as a solution to address the challenges of urbanization, including energy consumption and sustainability (Dijkstra and Henseler 2015). By leveraging technology, data, and citizen engagement, smart cities aim to realize optimize resource allocation and promote energy efficiency (do Nascimento and de Oliveira 2021). Energy efficiency is a crucial aspect of sustainable urban development (Mohd Dzin and Lay 2021). Several studies have investigated how smart city initiatives can contribute to reduced energy consumption (Mora, Deakin et al.). Highlighting the role of smart grids in optimizing energy distribution and integrating renewable energy sources (Eckhoff and Wagner 2017). Similarly, Min, Ryu et al. (2018) discuss the use of smart meters and real-time energy data to encourage energy conservation behaviors among residents.

Green Internet of Things (IoT) technologies play a significant role in smart city energy efficiency initiatives (Ejaz, Anpalagan et al. 2019). Explore the use of IoT sensors and devices for real-time monitoring and management of energy consumption in buildings and infrastructure (Ozili 2023). Additionally, emphasize the potential of IoT-based smart grids for optimizing energy distribution and reducing losses (Moura, Moreno et al. 2021). This literature review highlights the potential of smart cities to improve energy efficiency through technological innovation, renewable energy integration, infrastructure development, and supportive policies(Franke and Sarstedt 2019). The proposed survey questions provide a framework for gathering data on these variables and resident perceptions (Abir, Anwar et al. 2021).

The paper was based on a survey (n=126) where majority portions are from university students with a majority of male portion (Age range 20-25). Also, we limit the answers in likert scale only based agree to disagree, keeping no options for descriptive opinion or other form of expression by survey. Moreover, as a developing country Bangladesh is not implying all those technologies. Some are in planning phase for future implication. So, actual output where these technologies are established and respondents like job holders are surveyed can be suitable further research.

3. Methods

We started by reviewing google scholar, research gate and related news and articles to find out both overall and Bangladesh based scenario of Smart City with green iot current situation and future projection. Then based on reviewed paper which are well referenced and attached in appendix we decided on 3 independent variables "Green Internet of Things (G-IoT)", "Government Policy and regulations", "Technological Acceptance" and a mediating variable "Perceived Environmental Responsibility**"** that has effect on the result of independent variable over dependent variable "Smart City Development". We organized the survey questionnaire in likert scale which represent strongly disagree = 1 to strongly agree = 5. Then based on the survey result conducted "Reliability Analysis" in 'SPSS' and all the variables passed with strong indication for further analysis. Then, imported the data to PLS for conducting structural equation modeling which resulted in having 'Government Policy and Regulations' negative impact on dependent variable which we percieved otherwise at the beginning. Except that all showed positive relationship and passed various tests showing the paper's stronghold in multiple aspects, validating the main view of that paper.

4. Results and Discussions

4.1. Respondents' Profile

The demographic analysis of the participants is shown in Table: Age Group. We got 126 respondents. According to Table 1, 79 respondents were male, which is 62.7% of the respondent, and 47 respondents were female, which was 37.3% of the respondent. According to Table: Gender, Age group was segmented into 4 parts. 20-25 years old where we got the highest respondent from, which was 108 and it takes 85.7% of the total N. From 26-40 we got 9 respondents which was 7.14% of the population. Age 13-19 had 5.56% of the N, which is 7 people. And lastly 41 and above had only 2 respondents which is less than 2% of the total N. According to Table Profession, 82.54% of respondents were University students, which is 104. 11 respondents were having professional backgrounds (8.73%). 3.97% of the respondents are school going people or more likely teenagers. Lastly the 4.76% had chosen others options while filling-up the survey.

Table: Age Group

Age	Percent	Frequency
20-25	85.71%	108
26-40	7.14%	9
13-19	5.56%	7
40 and above	1.59%	2

Table: Gender

Gender	Percent	Frequency
Male	62.7%	79
Female	37.3%	47

Table: Profession

Profession	Percent	Frequency
University Student	82.54%	104
Professionals	8.73%	11
Others	4.76%	6
School and College Students	3.97	5

4.2. Reliability and Validity

Reliability: By using Statistical Package for Social Sciences (SPSS) we did pilot testing for reliability check. (Ellen C Lee 2014)We chose 20% population for Pilot testing (reliability testing), which was 25 respondents from 126 respondents. (Mohsen Tavakol 2011)Cronbach's Alpha's range was within the range of 0.70 to 0.95 or we can save above 0.70(Ahmed Imran Kabir 2022).

Table 1

	Reliability Statistics		
Variables	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
IV1	.926	.929	4
IV2	.892	.895	4
IV3	.921	.920	4
MV	.840	.847	4
DV	.794	.808	4

Validity: After checking the data once we use smartPLS for double checking. (smartPLS)By checking outer loadings we came to know that independent variable 1.1 (IV1.1) had less than 0.70 so we eliminate that question and respondent as well(NH Mohd Dzin 2021). After that we got output like table 2. We decided to keep the weighting scheme 'Factor" and maximum iteration to 2000 while testing the PLS Algorithm.

Table 2

	Dependent_Variable	**Independent_Variable_1**	**Independent_Variable_2**	**Independent_Variable_3**	**Mediating_Variable**
DV1	0.76				
DV2	0.704				
DV3	0.81				
DV4	0.862				
IV1.2		0.798			
IV1.3		0.903			
IV1.4		0.885			
IV2.1			0.702		
IV2.2			0.82		
IV2.3			0.83		
IV2.4			0.871		
IV3.1				0.825	
IV3.2				0.792	
IV3.3				0.851	
IV3.4				0.808	
MV1					0.876

MV2					0.883
MV3					0.864
MV4					0.816

4.3. Model Assessment

In terms of R Squared and Adjusted R Square the difference is so minimum in both mediating variables and dependent variables. From table 3 we can see that the r square is close to 0.60 or 60% as well. So we can consider these data as accurate and within the acceptable range which is more than 0.30 or 30%(Ozili 2022).

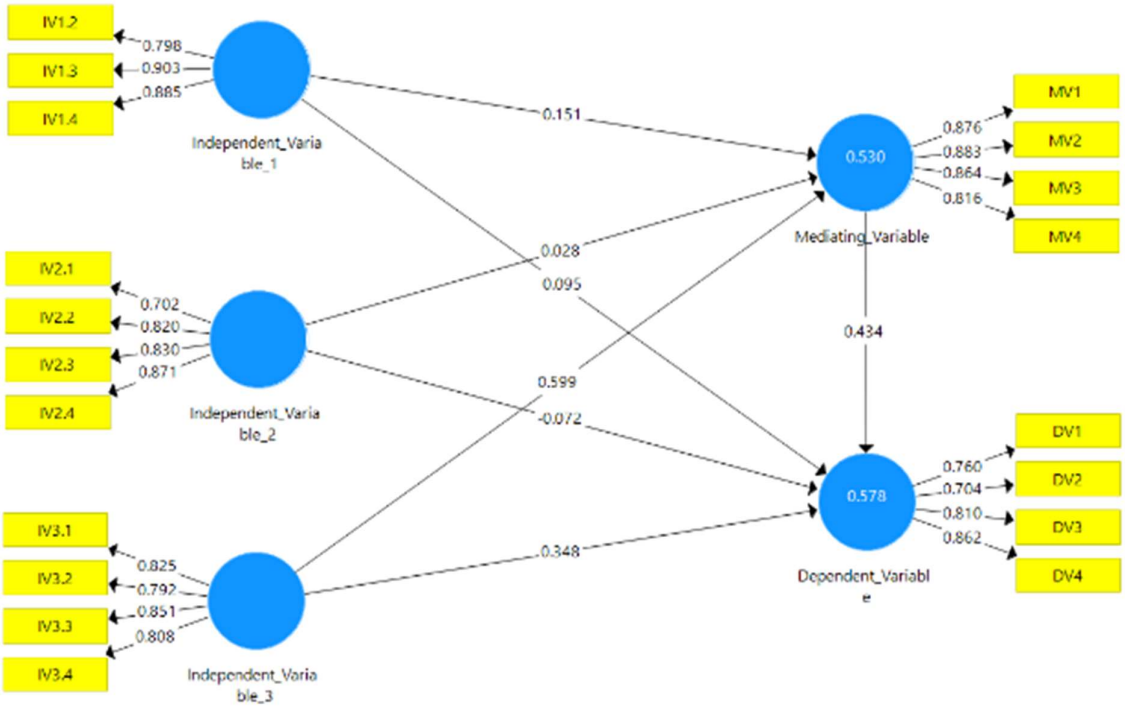
Table 3

	R Square	**R Square Adjusted**
Dependent_Variable	0.578	0.564
Mediating_Variable	0.53	0.519

According to table 4 we can see that rho_A is 0.821, 0.843, 0.845, 0.838, and 0.884, which were greater than 0.70, that means all rho_A were in acceptable range(TK Dijkstra 2015). Average Variance Extracted (AVE) were also within the acceptable range which is more than 0.50(Shrestha 2021).

Table 4

	Cronbach's Alpha	**rho_A**	**Composite Reliability**	**Average Variance Extracted (AVE)**
Dependent_Variable	0.796	0.821	0.866	0.618
Independent_Variable_1	0.828	0.843	0.897	0.745
Independent_Variable_2	0.822	0.845	0.882	0.653
Independent_Variable_3	0.836	0.838	0.891	0.671
Mediating_Variable	0.882	0.884	0.919	0.74



Heterotrait-Monotrait ratio of correlations (HTMT) is also within the acceptable range(George Franke 2019), which is less than 0.85.

Table 5

	Dependent_Variable	Independent_Variable_1	Independent_Variable_2	Independent_Variable_3	Mediating_Variable
Dependent_Variable					
Independent_Variable_1	0.651				
Independent_Variable_2	0.394	0.576			
Independent_Variable_3	0.834	0.837	0.597		
Mediating_Variable	0.822	0.677	0.465	0.835	

4.4. Findings

Independent variable 2 'Government Policy and Regulations' had the negative correlation with the dependent variable 'Smart City Development'. Which means people's perception was that Government, organizational partners and entrepreneurs are not directly influencing the smart city facts in terms of the Bangladesh region and it indicated an inverse relation between these two variables. But IV2 and the mediating variable 'Perceived Environmental Responsibility' had positive correlation. Except the relationship between IV2 and DV all other variables had the positive correlation with dependent variable and mediating variable as well. So we can say that each independent variable influences the dependent variable and mediating variable. Also, mediating variables had positive correlation with dependent variables as well. Regarding building of a smart city it requires governmental and organizational willingness which seems missing in this region according to the public opinion.

5. Conclusion and Recommendations

Based on the majority respondents it is clear that they support the idea of green IoT implementation for smart city development and optimization of resources.However, governmental regulation impact is not positive in that scenario. Our majority responders are male university students and by their response it is clear that they want to enjoy this privileges and want to make it sure for future generations with the mind of sustainable growth. Their positive attitude toward green initiatives are remarkable. Though, to make this topic more impactful one can do further research on female majority portion or job-holder or other professionals as well as on different age group people . Giving more option other than likert scale can change the outcome of these variables as well. So, a researcher can look into that. After all, that paper can come in to the benefits of many researcher studying on use of green technology for smart city development even if it is not properly implemented in their region yet , like Bangladesh. Based on that one can bring innovation that is suitable to its people as well. Leaving scope for big data based analysis, organizational and governmental development.

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Appendix: Surveyed Questions:

IV 1: Green Internet of Things (G-IoT)(Maksimovic 2017)

[1] Do you have any thoughts on how "Green Internet of Things" we could use to make cities eco-friendlier? I would like to know people's opinions on a scale of 0 to 5.
[2] Do you believe that G-IoT technologies can assist smart towns in saving energy and using cleaner materials?
[3] To which extend would you say that the benefits of G-IoT based technologies in the urban infrastructure can really improve the standard of living?
[4] How possible is that you will actually adhere to the use of G-IoT tools and devices to address the smart and environmental issues of the city?

IV2: Government Policy and regulations(Dong and Ullah 2023)

[1] Are the government regulations responsible for the way stakeholders are working together on the smart city projects?
[2] Do you agree that town authorities spend little in helping small businesses which could be the suppliers of goods and services to your smart community by setting up these business units?
[3] Do companies follow smart cities designing patterns and give the institutional entrepreneurship a chance?
[4] How far does the smart collaboration of different stakeholders promise the necessary synergy and smart innovations of the smart citizens?

IV3: Technological Acceptance(Albreem, Sheikh et al. 2023)

[1] Do green IoT technologies have the potential to lessen the energy consumption and emissions of carbon that are used by smart cities?
[2] Can the implementation of Green IoT help to create a healthier environment for various cities, such as pollution measurement and correction?
[3] What is your opinion about the green IoT solutions which are being used to promote the sustainable practices and green initiatives in the smart city development?
[4] How far do you consider Green IoT as one of the driving forces of future environmentally friendly and green urban development?

Mediating Variable: Perceived Environmental Responsibility(Masoomi, Sahebi et al. 2024)

[1] Do you agree that it is people's obligation to the environment that the environment should be saved?
[2] Is it necessary for you to take into account the environmental impact when you make a decision every day?
[3] Do you think it is your duty to participate or you have the moral need to contribute to the environmental conservation?
[4] Are you a supporter of green projects in your community?

Dependent Variable: Smart City Development(Albreem, Sheikh et al. 2021)

[1] How do you think technology, such as Green-IoT and Big Data, will influence the development of smart cities in the future?
[2] Scale wise what impact would the growth of infrastructure on smart cities capability to manage their resources well and allow them to grow without damage to the environment?
[3] Do you think the shifting of Green-IoT and Big Data to smart city projects gave way for the increase in individuals being actively involved in such initiatives?
[4] Are you saying that urban planners and policy makers have to choose between the short-term implementation of smart technologies and long-term development of smart cities?