

# How to Integrate the Data-based Strategies and Advanced Technologies into Efficient Air Pollution Management in Smart Cities?

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**Abstract:** Air pollution contributes to a critical environmental problem in various towns and cities. With the emergence of the smart cities concept, appropriate methods to curb associated with exposure to pollutants must have been a portion of appropriate urban development policy. This study presents a technologically driven air quality solution in smart cities to advertise energy-efficient and cleaner sequestration in these areas. It aims to address the issue of how to integrate the data-based strategies and artificial intelligence into efficient public sector pollution management in smart cities as a core part of the smart city definition. Exploratory research has been used in 152 smart cities, and environmental experts contributed to this study. It further addresses the technical criteria for implementing such a framework that the public administration uses to prepare the renovation of public buildings, minimize energy use and costs, and link these smart police stations to monitor air pollution as a part of integrated cities. Such a digital transition in resource management will increase public governance's energy performance, a higher standard of operation, and a healthier environment.

**Keywords:** smart cities, artificial intelligence, internet of things, air pollution

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## 1. Introduction

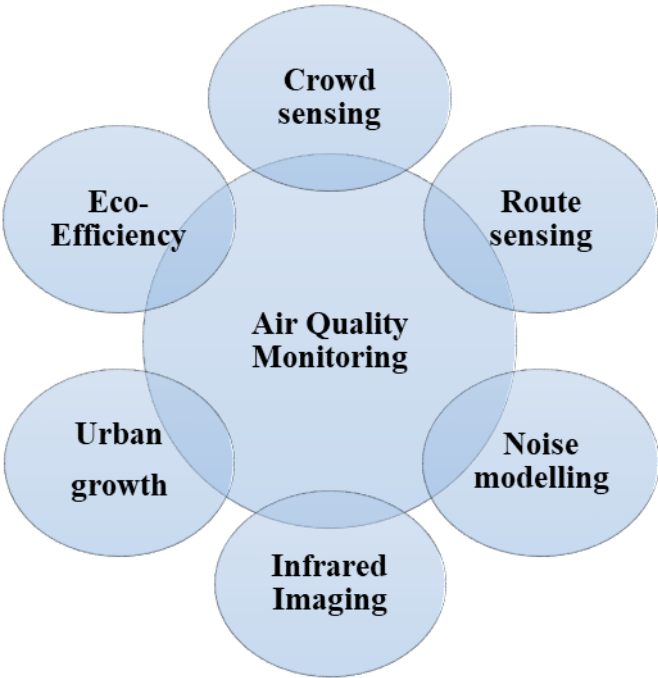
The population concentration in a few major cities continues to grow in the twenty-first century. In 1950, only 30% of the world's population lived in cities; by 2014, that figure had risen to 54%, and by 2050, it is projected to cross 66 percent [1]. Aside from the number of people, the average size of cities has grown [2]. This pattern was already apparent at the turn of the century, raising new challenges for governments to counter its negative consequences: traffic congestion, waste disposal, access to resources, and crime. Many technical companies adopted the smart city trend in 2005 as a potential solution to such issues. An abrupt rise in population trends towards urbanization has been observed recently [3]. The populations in cities are overgrowing and expected to rise in the future [4]. The socioeconomics in the urban areas has been found with increased complexity in their sustainability [5]. Increased populations in the cities have posed a severe challenge to the governments to cope with their health [6], pollution [7], waste management, and infrastructure [8]. Developing countries are challenging where the urbanization rate is up to 50% [9]. Smart cities address crucial issues of today's urban living, from transportation [10], energy [11], the environment to government, and citizen inclusion [12]. The concept of smart cities has revolutionized the modern world by providing a possible solution for the above problems by providing a unique blend of technology [13], data [14], and internet things [15]. However, the evolution of urbanized societies paved the way for the extensive emergence of databases [16], information communication technologies (ICTs). Such technologies include Big Data [17], Cloud Computing [18], Internet and Internet of Things [19], and Mobile Computing [10]. A blend of this urbanization and ICTs has led to the concept of smart cities [19]. A socio-technological concept is gaining more space in future cities striving to gain new development [20]. Smart Cities have equipped themselves with modern technologies to encourage efficient

performance for urban designs [21]. Data-based digitization has embarked on revolutionary changes in developing smart cities [8]. Such advances have created high growth in generating data [7].

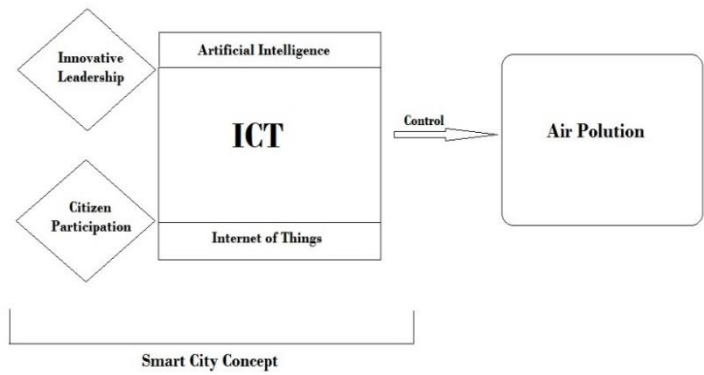
Air pollution cannot be ignored in these overpopulated cities in developing countries like Pakistan, where air quality worsens day by day [22]. A considerable rise has occurred in the types and number of emission sources of air pollutants in the region [23]. Intense industrial activity, a large population, an unprecedented rise in motor vehicle usage pose severe environmental impacts in the region [11]. Air pollution is a significant threat to the environmental departments, which is not updated for many years in South Asia, especially in Pakistan [7]. Considerable evidence is available that poor air quality is playing havoc with the health of the region [24]. The purpose of this study is to find a permanent solution to air pollution in Pakistan; An exploratory research has been carried out and tries to find the result that a data-based smart city can track and control air pollution.

## 2. Literature Review

Because of various anthropogenic factors, urban areas worldwide are witnessing an increase in air pollution levels, making adequate air quality forecasting a critical challenge for population health. Even though many prediction systems have been researched and modeled, many of them disregard the various effects of air pollution on each person. As a result, we present a novel background prediction model that combines an effective air quality prediction algorithm (using a Long Short-Term Memory Deep Neural Network) with information both from nearby sources of pollution [25]. Air pollution contributes to a fundamental environmental issue in various towns and cities. With both the emergence of smart cities concept, appropriate solutions to control people's exposure to pollutants must be part of appropriate urban development policy. The Eco-efficiency models have greatly influenced smart city development as several super-efficiency models have been used to calculate the eco-efficiency of different prefecture-level Chinese cities (Figure 1).



**Figure 1:** Possible data-based strategies to control air pollution in a smart city



**Figure 2.** A proposed research model for the present study

The idea of air quality-aware toll structures has been attempted to implement charging for drivers based on the route they take through the air quality-affected area. As a result, transport costs are related to the current level of pollution to deteriorate the already precarious situation more expensive for the environmental damage than when the situation is less severe on-site [26].

A few exploratory research types have explored the determinants of smart cities and their goals through an empirical hierarchical structure analysis. Such studies have indicated that

contact networks, public proceedings, and direct participants were essential for the review of each sub-factor [27].

Several analyses of the person specifications for crowd sensing configurations and the specifications for continuous speed with air monitoring functionality have been determined with their positive correlations [28]. The dynamic and graphical scope of development of the Spanish smart city has been taken into account in initiatives in mobility and environmental issues, which are at the heart of the development of a smart city [20]. Noise modeling is also a meaningful way to imagine and control noise emissions.

The outcomes of such research models have shown that such models are more reliable to model local noise propagation and have improved interpolation accuracy [29]. Since air pollution is a significant environmental threat, it has many adverse consequences on humans that need to be monitored. Information on air quality contaminants, such as methane, smoke, and other pollutants, is collected by public transport bus sensors, and information has been analyzed as busses and cars return to the source destination after going through stationary nodes across the area [15].

Besides, several outlines of the implying phase's approach (a specific variety of fuel or liquid biofuels) have been used, by utilizing borderline infrared imaging, to allow efficient implementation of low-emission areas in potential smart buildings [30]. Smart city development patterns are heavily dependent on local background influences. In particular, economic growth and urban architectural factors are likely to impact the city's digital direction, the spatial position that affects the smart city plan, and the population size correlated with congestion issues, which can be a significant component in deciding smart city's paths deployment [31].

### **3. Research Model and Hypotheses**

#### *3.1. Research Model*

Cities face significant challenges as a result of global urbanization patterns and urgent concerns concerning sustainability. The smart city concept was created as a strategy for interacting with cities as they become progressively prevalent across interconnected networks

and estimated to be infected on the use of Information and Communication Technology (ICT) to meet the needs of their people. All across history, technology has been an inextricable part of the evolution of cities. In recent years, there has been a change in the growth pattern of smart cities, with smart cities seeking to embrace sustainable practices through ICT and other smart solutions. According to previous research, these smart cities have struggled to integrate sustainable development goals into their innovative plans, focusing more on achieving competence goals than sustainability objectives and goals [32]. Current research involves a thorough review of current air quality benchmarks, which recommends implementing a given approach in an ideal smart city. The proposed model would assess air pollution in a defined metropolitan region, identify closed areas of elevated air emissions, and exchange people's knowledge toward low air pollution areas.

### *3.2. Hypotheses*

Pollution monitoring is becoming a progressively important issue. It has the potential to affect individuals and their health. Traditional approaches for predicting air pollution have limits. Artificial intelligence is one method that can create new possibilities for air pollution prediction. There are, however, several artificial intelligence-based methods, and determining the right one for the problem at hand can be difficult. This study presents basic computational intelligence-based models for forecasting air quality concentrations in potential smart cities. The following hypothesis was established to predict air quality for public health purposes

**H<sub>1</sub>:** Artificial intelligence positively effects air pollution.

The high complexity of the technologies used in IoT includes specialists, market internationalization, globalization strategies, and professional information. How information within organizations is handled, the latest and innovative knowledge management framework and transparent approach are called for, particularly by new revolutionary technology in the Internet of Things (IoT), to promote information flow. This research introduces a data-based surveillance program that incorporates IoT and environmental surveillance strategies to capture long-term environmental parameters and learn the frequency of pollution in a smart city [33]. Hence were devised the following hypothesis address the above issue.

**H<sub>2</sub>:** Internet of Things has positive influence on air pollution.

Sustainability enterprise is becoming a significant sub-discipline of the research into entrepreneurship by increasing the call for enterprise in a greener and more sustainable manner. Porter and Linde proposed that green legislation and sustainability are cost-effective and have hindered sustainable change. Customarily, environmental regulatory costs have concentrated on static cost impacts, disregarding any lowering efficiency benefits of innovation [34]. Nicolas et al. believed that prices underestimated product alternatives and overlooked the business's actual productivity is usually overestimated [12]. As a result, smart cities have received significant interest as initiatives to enhance urban growth. The overt and indirect impact of smart design enablers on economic efficiency has not been adequately computed. Findings of the study referenced above, two aspects, including the process variables of a smart city and the expansion of data-based monitoring, should be regulated at the same time if e-government managers want to pursue better pollution control approaches for smart cities. The possible link that needs to be correlated is as if there is a significant relationship between the effects of data-based smart cities and the issue of controlling air pollution.

**H<sub>3</sub>:** Innovative leadership has positive relationship with air pollution.

The influence of pollution on the quality of life, well-being, and human beings' efficiency needs to be addressed, mainly when managed to keep in more innovative buildings. Tesanovic and Vadgama believed that monitoring these environmental factors promotes the implementation of appropriate strategies to reduce the harmful effects of sub-optimal pollution on the respiratory system due to its surveillance by the previous ones [30]. So, keeping in view these factors, this research also requires if there exists a positive/negative relationship between environmental factors and the environmental monitoring system.

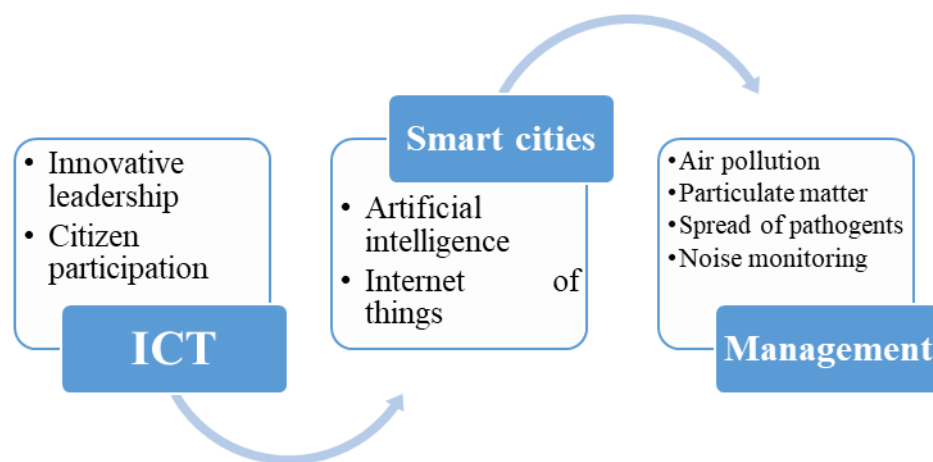
Sustainability needs to be rethought to debate the urban planning of the city and create sustainable environments. Some aspects of the development in urban lifestyle in city design have previously never been considered significant. Over the years, citizen action initiatives for environmental awareness and understanding have been introduced, but most such works are fundamental, i.e., task development, preparation, and analysis are conducted by trained

researchers, and people serve as participants. Our goal is to show how citizen data can be used as a "tool" to improve public awareness of air pollution by involving communities and local participants. Neirotti believed that today, citizens are very concerned with the quality of living in their cities, particularly concerning pollution. Air pollution is of great significance to plan our activities and take precautionary measures for our quality of life [31]. Also, the measurement of interaction with air pollution in a smart city can be attributed to being a positive way to make the world safer and healthier.

**H<sub>4</sub>:** Citizen participation positively influence the air pollution

#### 4. Research Design

All across history, technology has been an inextricable part of the evolution of cities. In recent years, there has been a change in smart cities' growth pattern, with smart cities seeking to embrace sustainable practices through the use of ICT and other smart solutions [35]. According to previous research, these smart cities have struggled to integrate sustainable development goals into their smart plans, focusing more on achieving competence goals than sustainability objectives and goals. The present study was intended to track the environmental effects of a smart city and track the introduction of ICT and IoT in Pakistani cities. Punitive optional elements have also been attempted by ICT and IoT (Figure 3).



**Figure 3.** Organogram of data-based pollution monitoring in smart cities



#### *4.1. Research Method*

There was an experimental method for the investigation of the above-cited parameters. The project group developed a questionnaire—discussion with a more significant stakeholder of policy leaders. The evaluation has been performed to demonstrate how well the smart city can be established using the current plan, how the installation of detectors is essential for building a smart city, and how we must use data from new sensors to execute advanced data analytics city design.

#### *4.2. Data Collection and Measurement*

This segment indicates that it has been used to establish associations between various urban indicators. An interactive questionnaire on air pollution was developed with the views of government officials. It is simultaneously passing on original research and critical details on air pollution fundamentally. The designed air pollution quiz was found to play online through google docs.

The full details of public office holders were 152 persons, with a significant range of factors suggesting their physical, regulatory, and pollution strategic planning attributes have been collected. The initial prediction models are focused on pollution optimization techniques, and data were created for this analysis. The intelligent energy management idea was proposed, which will make more rigorous use of IoT platforms, data preprocessing data, and data science designing to assist in this process. The decision-making method on electricity efficiency and restoration initiatives.

All data preprocessing tasks were followed by the clustering process. Missing values for each input attribute have been replaced by the mean sum of the variable's cost-effective advertising. Factor elimination was influenced by the usage of regression ratios for continuous variables and numerical input variables.

### **5. Results and Discussion**

The maturity of data analytics in the smart world has opened up—a massive array of possibilities for generating new interest. To shifting forward, there are many obstacles to overcome to such development. These are multifaceted and can be approached by several multi-disciplinary viewpoints. In the latest days, the smart city development concept has drawn the interest of multinational businesses by introducing a business paradigm. The growing market for the future development of smart city innovations and massive technology has increased. Smart technologies provide a wide variety of application types. There are a variety of smart objects installed in the region. The dream of the smart community, though, is to incorporate such a vast volume. Data from various sources; data convergence inside the smart city is among the main issues tackled. Correlation analysis is a powerful tool used to assess the association's strength between the two quantitative variables. A higher, linear relationship between two or more variables indicates a positive dependency between each other, while a low correlation tends to mean that the variables are not very closely related (Table 1).

**Table 1.** Correlation of different variables for a data based monitoring system in a smart city

Factors	Artificial intelligence	Internet of Things	Innovative leadership	Citizen participation	Air pollution
Artificial intelligence	1.00	0.446	0.407	0.427	0.602
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
Internet of Things	0.446	1.000	0.446	0.422	0.296
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
Innovative leadership	0.407	0.446	1.000	0.303	0.261
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001
Citizen Participation	0.427	0.422	0.303	1.000	0.436
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
Air pollution	0.602	0.296	0.261	0.436	1.000
Sig. (2-tailed)	0.000	0.000	0.001	0.000	0.000

N=152, p<.01

The regression analysis has been performed on predictor factors since it is a reasonable way of determining the possibility that one variable will anticipate another. Multicollinearity exists

when two or more predictors in the model are correlated and provide overlapping response information. Multicollinearity was evaluated by variance inflation (VIF) and tolerance considerations. If the VIF value reaches 4.0, or if the tolerance would be less than 0.2, there will be multicollinearity 36 (Table 2).

Table 2. Multi regression data of dependent predictors in present research model

IV	DV	B	Beta ( $\beta$ )	t	F	R	R Square	Sig.	Multicollinearity	
									Tolerance	VIF
AI	AP	0.649	0.602	9.245	85.468	0.602	0.363	0.000	1.000	1.000
IOT	AP	0.319	0.296	3.800	14.437	0.296	0.088	0.000	1.000	1.000
IL	AP	0.380	0.261	3.315	10.987	0.261	0.068	0.001	1.000	1.000
CP	AP	0.618	0.436	5.935	35.226	0.436	0.190	0.000	1.000	1.000

N=152,  $p < .01$

### 5.1. Role of Artificial Intelligence (AI)

Cities are gradually moving to advanced solutions to tackle financial, economic, and environmental concerns morphology and a number of things 9. The new idea of Smart Cities actively promotes this possibility by encouraging the convergence of sensors and data analysis through the Internet of Things (IoT). The implementation of AI has started to gain growing interest in the sense of smart cities. Given the importance of this question, the purpose of this paper is to undertake a research study to examine the position of AI in the various industries of smart cities. As the earth's climate change continues, the consequences of climate change are deteriorating. There had been 772 climate and catastrophe occurrences in 2016, three times the amount that occurred in 1980 [37]. So our first hypothesis stems from the fact that if AI positively affects air pollution. The work leads to the philosophy of successful community planning provide templates that should be used at the point of data analysis to predict and maintain emission reduction in a smart city with acceptable precision. The most reliable model was built in this research. It was achieved by utilizing the strengths of three different models. The findings suggest the infrastructure of the smart city's smart energy management, with the creation of forecasting as an integral part of prevention and control of pollution in a smart city.

The management network of growing smarter ecosystem (smart cities) has a number of co-protocol gateways that enables it to handle and centralize all details, irrespective of the fundamental interlinking infrastructure [38]. The correlation among five variables related to the purpose of the study was to find out the effect of data-based smart cities focusing on the issues of controlling air pollution. Further, it showed a significant positive relationship between every two variables. The Relationship of artificial intelligence is significantly positive with internet of things ( $\rho=.446^{**}$ ,  $\text{sig.}=.000$ ), Innovative leadership ( $\rho=.407^{**}$ ,  $\text{sig.}=.000$ ), Citizen Participation ( $\rho=.427^{**}$ ,  $\text{sig.}=.000$ ), Air pollution ( $\rho=.602^{**}$ ,  $\text{sig.}=.000$ ). Results imply the fact that IoT technology, together with AI, can form the basis for enhanced and potentially completely new goods and services in a smart city to control pollution through data-driven signals. AI also simplifies both the navigation of inspection devices (sensors) and the detection of defects throughout the data gathered by them.

### *5.2. IoT Influences in Controlling Pollution*

Air quality has a leading position in public wellbeing which has a stronger effect on life expectancy. As this paper reveals, IoT-based air quality monitors a network comprising of a clean air sensor, so this framework relies on IoT and cloud computing innovation to monitor pollution anywhere at any time to find if the Internet of things has a positive influence on air pollution [13]. The motivation behind this investigation is to assess the usefulness of the IoT in the use of human capital to reduce emissions in a smart city.

In fact, the researcher used variables such as learning and growth, healthy and protection, recruitment, employee engagement, security & privacy to detail the success of IoT among the participants in this report. The IoT, based on the available innovation review of an IoT, makes an analysis and research on the IoT devices in terms of pollution management [39]. The relationship of IoT is significantly positive with innovative leadership ( $\rho=.446^{**}$ ,  $\text{sig.}=.000$ ), citizen participation ( $\rho=.422^{**}$ ,  $\text{sig.}=.000$ ), air pollution ( $\rho=.261^{**}$ ,  $\text{sig.}=.000$ ). the findings suggested that the IoT might be a platform with a wide range of technical support, including radio frequency

identification technology, virtualization technology, logistics management, e-commerce technology in a way to control the pollution levels in a generalized smart city.

### *5.3. Role of Innovative Leadership*

Infrastructure-focused smart city development that engaged in building cutting-edge cloud infrastructure for crime prevention, traffic relief, environmental protection, and disaster relief have now been shifting to center on internal process innovation through comprehensive employee education and training about smart city principles, with an emphasis on data-driven policymaking rather than infrastructure-driven decision making [41]. The goal of this study is to include some analytical data on the relationship around environmental leadership as well as the cost of pollution control across multiple organizations. Innovative leadership has earned adequate attention from the corporate market in recent years, but few researchers have analyzed safety structures and conditional circumstances that connect environmental leadership to strong performance. There has been emphasis regarding that innovative leadership has a positive relationship with air pollution.

In order to get a deeper understanding of the importance of opinion leadership on pollution in sustainable smart cities, this study looked at the interconnections between opinion leadership, motivation, and political commitment to address ever-increasing pollution. The finding of present research showed that a relationship of innovative leadership is significantly positive with citizen participation ( $\rho=.303^{**}$ ,  $\text{sig.}=.000$ ), air pollution ( $\rho=.602^{**}$ ,  $\text{sig.}=.001$ ) [42]. The relationship of citizen participation is significantly positive with air pollution ( $\rho=.436^{**}$ ,  $\text{sig.}=.000$ ). Most importantly, the research shows that creative leadership provides a major contribution to the participation of individuals in processes or media that are motivated to obviously help individuals participate in pollution control strategies.

## **6. Conclusion and Policy Implication**

This study addressed an energy-efficient and easier sequestration technology-led approach for smart cities. It has also addressed how data-based solutions and artificial intelligence can be incorporated into effective control of public emissions in intelligent cities as a central field of intelligent environment. The predictive model is made possible by data-gathering networks, a regression analysis using variance reduction approaches. Variance analysis of all the hypotheses under study has proved them acceptable (Table 3). Hypothesis 1 was accepted as R square for artificial intelligence explains 36.3% of the variance in the factor "reduce air pollution" that was significant ( $F=85.468$ ,  $\text{sig}=.000$ ).

Table 3. Analysis of variances with respect to results of participants

Hypothesis	Factor	F-Value	Sig*. Value	Status
H <sub>1</sub>	artificial intelligence positively effects air pollution	85.468	0.000	Accepted
H <sub>2</sub>	Internet of things has positive influence on air pollution	14.437	0.000	Accepted
H <sub>3</sub>	Innovative leadership has positive relationship with air pollution.	10.987	0.001	Accepted
H <sub>4</sub>	Citizen participation has positive influence on air pollution.	35.226	0.000	Accepted

\*Average of dependent predictor

Hypothesis 2 accepted the fact that R square for the internet of things explains 8.8% of the variance in the factor "reduce air pollution" that is significant ( $F=14.437$ ,  $\text{sig}=.000$ ). Hypothesis 3 was stood accepted as R square for innovative leadership explains 6.8% of the variance in the factor "reduce air pollution" that was significant ( $F=10.987$ ,  $\text{sig}=.000$ ). Hypothesis 4 was accepted as R square for citizen participation explained 19.0% of the variance in the factor "reduce air pollution" that was also significant ( $F=35.226$ ,  $\text{sig}=.000$ ). Beta values show that the most robust ( $\beta=.602$ ) factor to reduce air pollution. While second is citizen participation ( $\beta=.436$ ), the third is IoT ( $\beta=.296$ ), and the last is innovative leadership ( $\beta=.261$ ). All the factors have a significance value below .05 that shows their unique contribution in reducing air pollution.

From the report, most respondents concluded that the security and validation of data might be very beneficial for controlling air pollution in a proposed smart city. The goal is to reduce

health hazards and increase understanding of the consequences of exposure to air pollution. This report discusses the main issues of an on-the-spot pollution framework, such as with sensors, the creating technology on the IoT, and the collection and transmission of data across communication networks. Protection is a key priority of the proposed IoT solution. All other elements of the device are security-related. The IoT protection administrators are expected to enforce such network protection practices when implementing new technology. Hypotheses have been developed using the previous literature as context. The Idea discusses IoT safety issues in the channels between IoT gateway systems and the cloud infrastructure to which data is transferred. The installation of protection complies with current protocols, practice guidelines, and requirements to guarantee a secure and robust solution for environmental issues in the conceived smart cities [43]. The solution also allows the data collected to be interpreted and analyzed using data analytics to construct maps of pollution.

The empirical findings of the study designated that the complex proceedings are leading to successful and sustainable smart cities. Through the coordination of their resources and activities by individuals and organizations on innovation management and leadership platform. In the context of the developmental scene and the social and cultural capacities of these actors, the numerous yet complementary relations have to be further harmonized. The urbanization interests are growing by prioritizing more technologically powered manufacturing processes and service distribution to become 'intelligent' [44]. While the proliferation of these modern organizations, the manner in which the lead organization is practiced is well known. This study has exposed a discursive trend on the way public bodies, private companies, and community leaders "see" and "do" in these locally-based contexts, and concludes that economic and social gains can be achieved by leveraging the social and spatial complexities of "intelligent" growth of smart cities.

**Author Contributions:** Shehzad Khurram designed the research framework, conducted the survey, and analyzed the data; Seunghwan Myeong contributed to conceptualization, methodology, and editing.

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