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EDITED BY
Dharmendra Singh Rajput,
VIT University, India

REVIEWED BY
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Federal Rural University of Rio de Janeiro, Brazil
Brijesh Bakariya,
I. K. Gujral Punjab Technical University, India

*CORRESPONDENCE
Muhammad Khan,
khanmuhammad59@yahoo.com

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Impact of technology on upgrading slums and the moderating role of upstream influences: a contemporary approach to urban planning

Muhammad Khan[1,2]*, Komal Bilal[3] and Gohar Alam[4]

[1]Nanjing Agricultural University, Nanjing, China, [2]School of Public Administration, Nanjing Agricultural University China, Nanjing, China, [3]Ghazi University, Dera Ghazi Khan, Pakistan, [4]Department of Tourism, School of Geography and Tourism, Anhui Normal University, Wuhu, China

This study aimed to determine the effect of technology on the upgradation of slums in Islamabad, along with the moderating role of upstream influences between them. With this concern, the researcher used a quantitative research design, and to accumulate the data, a closed-ended survey questionnaire was chosen. The sample size considered in this research was 293 participants belonging to the urban planning sector of Islamabad. To evaluate the data and hypothesized model, structural equation modeling (SEM) was used. It was also revealed that upward influences moderated the association between technology and slum upgradation significantly, particularly regarding governance, religion, and gender roles. However, this research is limited to Islamabad only; therefore, the implications of this study cannot be generalized. Consequently, it has been recommended that upward influences based on crime and mafia, along with governance, should be controlled to upgrade Islamabad-based slums.

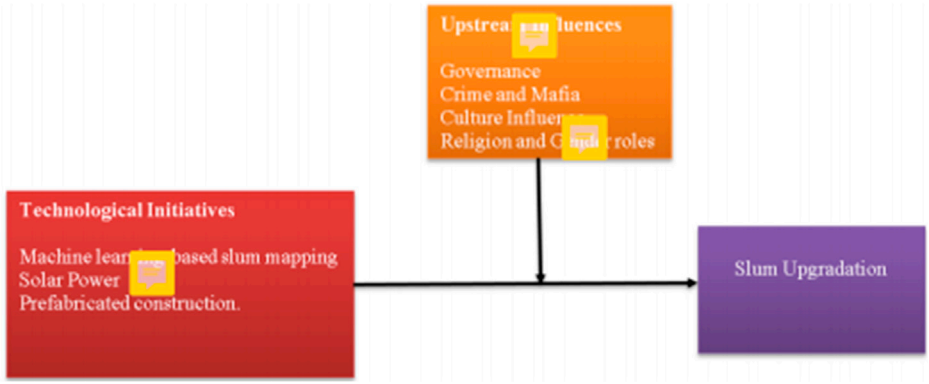
KEYWORDS

technology, machine learning, governance, crime and mafia, cultural influence, religion, gender

1 Introduction

Over the years, urbanization has emerged as one of the major issues, yet the population of different cities around the world has not been considered. According to Igwe (2018), the United Nations Development Programme (UNDP) has set one of the Millennium Development Goals (MDGs) that aims to enhance the lives of at least 100 million slum dwellers by 2020. Hence, to accomplish this aim, governments of different countries around the world have started introducing different slum upgradation programs. In accordance with the report of UNCTAD (2015), the majority of the world's population lives in urban areas, and by 2050, this is expected to grow to two-thirds, which is likely to be mainly driven by developing nations. As per the same report, 90% of the expected increase in urban population by 2050 is likely to take place in Asia and Africa. Hence, the upgradation of slums has become one of the major goals of most countries.

It is commonly accepted that slum upgradation involves the enhancement of the physical environment, which may include waste collection, sanitation, water supply, drainage, electricity, street lighting, and road paving (Tiwari et al., 2020). In addition, it



GRAPHICAL ABSTRACT

may also include the enhancement of accessibility to social, educational, and health services and increasing the living standards of the people. According to Rup wate et al. (2018), the living conditions within slums can differ among different countries and even among residents within the city or country. In this regard, some of the major challenges that are found to be associated with the issues of slum development in different parts of the world include rapid rural–urban migration, population growth, and the failure of the urban government. In the existing body of literature, several issues related to slum upgradation have been identified in the context of different countries; however, the significance of the influence of technology usage on slum upgradation has not been well-researched. Particularly in the context of developing countries like Pakistan, where the issues of slum upgradation are high, there is a lack of evidence in the existing literature regarding the impact of technology on the slum upgradation process. Hence, this study aims to fill this research gap by providing more clarity on the influence of technology on upgrading slums in the context of urban planning in Islamabad.

The government of Pakistan is adamant about eradicating the problems of slums by upgrading them, and in this regard, various efforts and strategies have been made by the government of Pakistan for the upgradation of slums. However, the problem still exists, and it is believed by a member of the Prime Minister's Taskforce, Jawad Aslam, that before promising to build five million houses over the next 5 years, there was not enough homework done by the ruling Pakistan Tehreek-e-Insaf (Griggs et al., 2013). It has been observed that compared to the other cities in Pakistan, the issue of slums is more prominent and prevalent in the city of Islamabad, and concerns over the proliferation of slums in the city has increased. Two decades ago, in Islamabad, there were only 12 slum areas, but presently, there are more than 42 slums in the city (Gulf News, 2018). This clearly shows that this problem has exacerbated in recent times and requires serious attention from the government.

Thus, it is imperative for the government of Pakistan to focus on urban planning and take effective measures to upgrade slums in the city of Islamabad by providing them with adequate living conditions. It has been observed that by using effective technology, including tools such as artificial intelligence (AI), slums can be upgraded by the government, increasing the efficiency of government efforts in providing social, economic, and constructive support, which will help make these areas environmentally friendly (Duque et al., 2017). The reason is that the assistance of new technologies, such as solar power plants, prefabricated construction, and better land mapping, can greatly help upgrade slums and reduce the costs of housing by 20 to 30% (Leonita et al., 2018). Therefore, with the help of technology, there can be better land use, and housing can be made cheaper. Slum upgrading strategies should be adopted by the government of Pakistan, and these strategies should be based on new technologies. However, it has been observed that upstream influences are considered a very important problem in Pakistan, and more specifically in Islamabad, due to which the effects of slum upgrading strategies are being moderated (Turleyet al., 2013). Therefore, it is very important to incorporate technology and AI into the upgrading programs of slums, including community engagement, improving the financial and social environment, and enhancing access to health and social care.

Thus, the present study is intended to analyze the impact of technology on slum upgradation by considering the moderating role of upstream influences. The main motivation behind conducting this study is that the problem of slums is considered one of the most important problems in Pakistan, more specifically in the city of Islamabad, where the number of slum areas has drastically increased in the last two decades. The paramount cause behind this is a lack of urban planning (The News, 2020). However, despite the importance and necessity of resolving this issue, there are not sufficient studies that have highlighted the problem of slums (Habib et al., 2019). It has been observed that there have been various studies conducted related to slums and urban planning, as it is an international concern; however, in the context of Pakistan, such studies are scarce (Corburn and Sverdlik, 2017). In addition, when it comes to Islamabad, there is very little research conducted. Therefore, this is considered the most important gap in the literature.

The other most important gap that exists in the study related to slums and urban planning in the context of Pakistan is that no study has considered moderating the variables in the relationship between technology and slums, and hence, in this study, efforts are made to overcome this gap by considering upstream influences as a moderating variable (Rabbani et al., 2019a). This study will provide significant insights to the government, urban planners, and policymakers, which will help them take effective technological measures to upgrade the slums in Islamabad.

Therefore, taking these views into account, the following objectives have been created for the study:

- ❖ To assess the impact of technology on upgrading slums in Islamabad.
- ❖ To study the moderating role of upstream influences in the relationship between technology and slum upgrading strategies.
- ❖ To highlight the key technological factors in upgrading slums in Islamabad.
- ❖ To provide recommendations to the government of Pakistan for enhancing the conditions of slum areas in Islamabad.

The research question of the study is designed as follows: what is the impact of technology on slum upgradation, considering the moderating effects of upstream influences?

2 Literature review

In the previous section, a thorough review of the research background was presented, along with the key aims and objectives of this study. This section is dedicated to conducting a comprehensive review of previous literature with respect to the impact of technology on slum upgradation. In an urban settlement, the identification of slums is considered an imperative step, as, without it, the process of formulation of pro-poor policies is not possible and effective urban planning cannot be ensured. When it comes to urban planning, it refers to the process of developing and structuring cities (Habib et al., 2019). Urban planning is done to transform cities and backward areas so that these areas can become capable of generating income, which helps the economy bolster and thrive (Kamboyo et al. (2016). It has been analyzed that urban planning is considered an imperative method that propels the government to comprehend the infrastructure and landscapes of the country and improve these areas with the intent to entice the attention of tourists and increase the value of the state. In the context of Pakistan, the upgradation of slum areas has become one of the major concerns for the government. As mentioned in the study of Hussain et al. (2019a), the Pakistani government only owns the legal slums, and they allocate funds accordingly for the infrastructural development of those areas. However, the unauthorized slums are considered illegal and are not considered for development funds. In accordance with the same study, unauthorized slums are present in the surroundings of the residential sector of Islamabad, where people lack basic needs, and the issues of poor living standards and deteriorated infrastructure are prevalent. On the other hand, the study conducted by Hussain et al. (2019b) provided evidence from Rawalpindi, Pakistan, where the issues of slum upgradation have significantly increased. In this regard, the negative impact of an open drainage system on the rental values of the surrounding property has been found. The results of the same study also revealed that the prices of house rent decreased by approximately 10% because of the open drainage line in the area. This signifies the importance of technology for slum upgradation, as the use of updated technologies and methods can enhance the process of urban drainage and the overall process of slum upgradation.

The significance of upgrading slums in the context of Pakistan has been recognized in previous literature. As per the study of Baig, Nawaz, and Idrees (2020), the Government of Pakistan needs to revitalize the underdeveloped slum areas because a large number of people are living under poor conditions. Therefore, the government is responsible for offering better living conditions to uplift the quality of the living standards of their people. Similarly, in accordance with the study of Liu and Jiang (2020a), slum areas are the major issues faced by most of the residents and local population in Pakistan because of the absence of basic necessities in these areas. Moreover, local citizens also tend to avoid renting a house in slum areas due to problems such as noise, crime, energy issues, pollution, and other environmental issues, which negatively impact house rental prices. Hence, the upgradation of slum areas in Pakistan is essentially needed to address the issues related to the growing population and rural–urban population.

As the number of slum areas is increasing all across the world due to poor health and sanitation facilities, a poor financial and social environment, a lack of governmental effort, and a lack of community engagement, there is growing concern about the slum areas (Liu and Jiang, 2020b). Pakistan is also considered one of those countries where the issue of slums is very important. In comparison with other cities in Pakistan, there are a maximum number of slums in the Islamabad Capital Territory (ICT), and the slum areas in Islamabad are considered to have very pathetic conditions. These areas are greatly deprived of basic and vital civic services, such as basic health and education facilities, sewerage, and water supply (Hussain et al., 2019a).

In addition to the above information, it has been reported in The News (2020) that, as opposed to its urban region, the population in the rural areas of Islamabad has increased, which is an extremely unusual and startling finding. However, this is completely irrespective of the population growth across Pakistan, where the urban population shot up against the rural areas. If the current census is compared with the census of 1998, the proportion of Islamabad's rural population has increased by 15%, which is a shocking development; on the other hand, in other areas of Pakistan, there is an increase in the urban population. In the three censuses conducted in 1981, 1998, and 2017, the population of Islamabad was 340,000, 810,000, and two million, respectively. In addition, there is a 60%, 65%, and 50% ratio of the urban population, respectively (Turley et al., 2013). However, in Islamabad, where there is above 6% growth in rural areas, the overall highest population growth is 4.9%.

The findings of various studies indicate that there is considerable growth in slums in Islamabad. However, there are some other intriguing findings explored in these studies that echoed that there is no complete information about these growing communities of slums as the ethnic and linguistic profile of new slum dwellers has not been shared by the Pakistan Bureau of Statistics (PSB) yet (Chaudhuri, 2017; Rabbani et al., 2019b). However, in relation to this, it has been predicted by many demographic experts that when the data are provided, there will be an increase in the number of slums in Islamabad, making it a majority Pashtu-speaking region (The News, 2020).

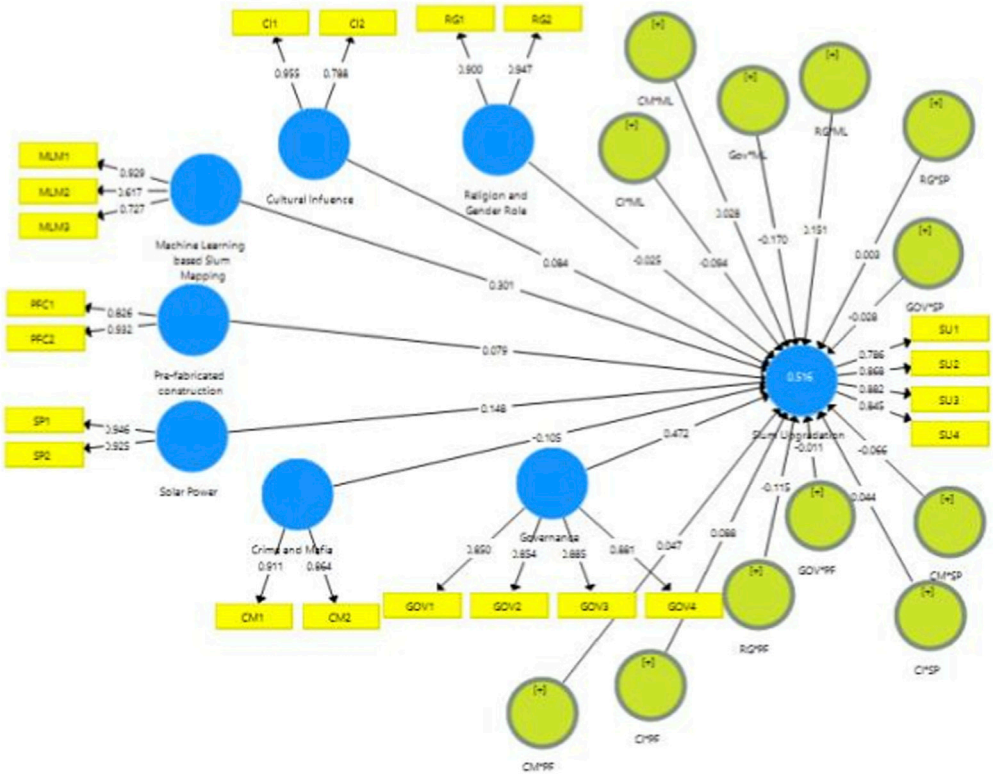


FIGURE 1
Measurement Model.

The fact that slums areas in Islamabad are increasing cannot be denied, and this problem is getting exacerbated day by day. However, the efforts that are being made and the steps that are being taken are not proven to be effective, owing to which there is no improvement in the problem (Mugamba, 2016). In relation to this, it has been observed that conventional and old methods are still employed for slum detection and upgrading their condition, which is one of the most important reasons why the Government of Pakistan is unable to solve this problem (Turleyetal, 2013).

Globally, every one in three residents is a slum dweller (Ibrahim et al., 2019a) (Figure 1). This reflects a major issue for urban housing because most of these adjustments are not seen on official government maps. This also increases the challenge of completely understanding the different dynamics of the cities. Moreover, there is uncertainty about the ways people opt for certain locations to develop their homes and then settle themselves. In this regard, the process of monitoring and diagnosing cities becomes more complicated, which eventually hampers the ability of authorities to offer adequate services and improve the living standards of urban dwellers. However, in recent years, major advancements have been made in urban modeling. For instance, by considering cities as complicated systems, it has been observed that the shapes and forms of cities follow similar developmental paths based on fractal dimensions and scaling laws that enable a bottom-up progression of geometry within a temporal scale (Ibrahim et al., 2019b).

A theoretical dynamic model has also been introduced that encourages several forms of urban sprawl in a city (Kamalipour et al., 2019). On the other hand, an agent-based model that discovers the formation of slums in the context of India has also been introduced (Esposito De Vita, 2018). However, despite several attempts at spatial modeling of residential location choice and urban expansion, the process of recognizing informal areas within cities has remained one of the missing areas in different urban models. The issues of image and visibility are further exacerbated by globalization, and the growing flows of tourists and the change to an information economy have retained new economic significance for the city's image as a brand. As per the widely accepted view, cities contend to draw sufficient flows of flexible capital and develop themselves as prominent global cities by producing urban iconography and spectacle (Panek and Sobotova, 2015). The development of higher railways and freeways, together with office and residential towers, implies that the middle-class gaze enters further across the urban landscape, where informal adjustments are then viewed as the new zone for redevelopment.

The significance of computer vision and deep learning technology has been widely acknowledged in the previous literature, as they promise to solve complex problems in a wide range of domains. Particularly in urban literature, these technologies have been recognized as crucial for the establishment of autonomous vehicles and smart cities (Esposito Vinzi et al., 2010). However, there is a lack of evidence in the existing literature regarding the role of these technologies in informal urban zones in developing countries. The advancement in the fields of computer vision and deep learning has made it easy to understand the different dynamics of cities. In this regard, the use of computer vision has provided an opportunity to analyze the missing aspects of city dynamics. The large-scale

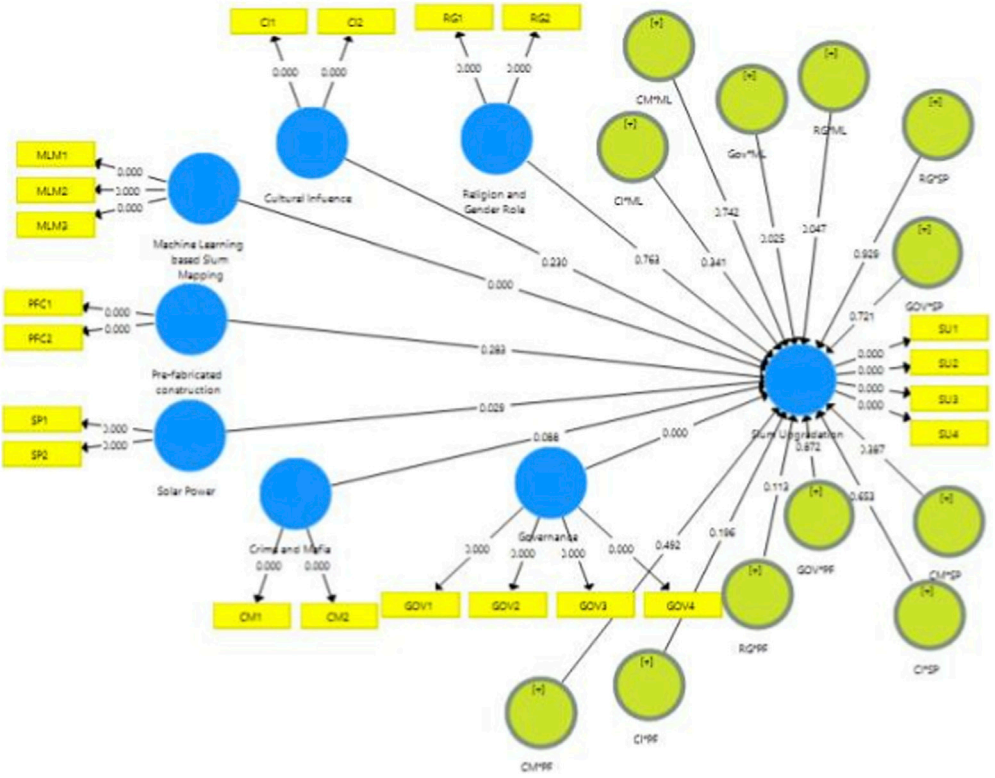


FIGURE 2
Model after Bootstrapping.

analysis of digital patterns and images of captured landscapes (Figure 2), which cannot be recognized by human eyes, can provide a solution to different urban issues (Kamalipour and Dovey, 2019). These techniques are commonly used to attain useful information and obtain important components from images in a similar manner to how urban scholars use them to observe cities. Big data, on the other hand, has been recognized as another important technology and a useful method for planning. The use of an analytical model of urban planning that is developed based on the big data method can significantly enhance practical problem-solving abilities in slum upgradation (Panek and Sobotova, 2015). This can ultimately support the development of smart cities and also encourage new urbanization. The method of big data has been extensively used in urban planning. However, currently, there is still a need for copious data collection in the popularization of big data utilization in urban planning.

The traditional methods of slum detection are very costly and time-consuming, and there is a need to integrate new technology with AI (Meth, 2017). However, it has been observed that there are three key factors or technological tools that can play a crucial role in this regard: 1) machine learning-based slum mapping, 2) solar power, and 3) prefabricated construction (Gina et al., 2018).

Machine learning-based slum mapping can play a crucial role in mitigating the problem of slums. There are three important features that are combined with machine learning-based slum mapping: textual, spectral, and cultural features. This method of slum detection is based on AI, as it uses machine learning approaches. In this regard, for slum detection, the random forest (RF) classifier is considered the most effective method as very high-spatial resolution (VHR) imagery is used by it, which can help in the process of effective slum extraction (Duque et al., 2017). Moreover, other important machine learning-based methods can also be used for slum identification, such as neural networks (NNs) and support vector machines (SVMs). With this help, the prices of houses can also be brought down by the government. For instance, in cities, ownership of land is not clear as many areas are not mapped at all (Leonita et al., 2018). Thus, with the help of this technology, the settlement can be mapped, and slum dwellers can be given addresses. Therefore, based on this information, the following hypothesis can be formulated:

H1: Machine learning-based slum mapping has a significant impact on slum upgradation.

The other important factor in consideration is the use of solar technology. It has been observed that the availability of electricity is one of the serious problems in slum settlements in Islamabad, and hence, by using solar technology, this problem can be solved to a great extent. The reason is that Pakistan receives a lot of sunlight, and therefore, solar technology can be very successful in providing electricity to these slums. Therefore, by setting up solar projects using solar technology, the government can solve the problem of electrification, which will eventually help in improving the quality of the slums and pave the way for further development (Baruah, 2010; Schwengel, 2011). The use of a new construction technique is

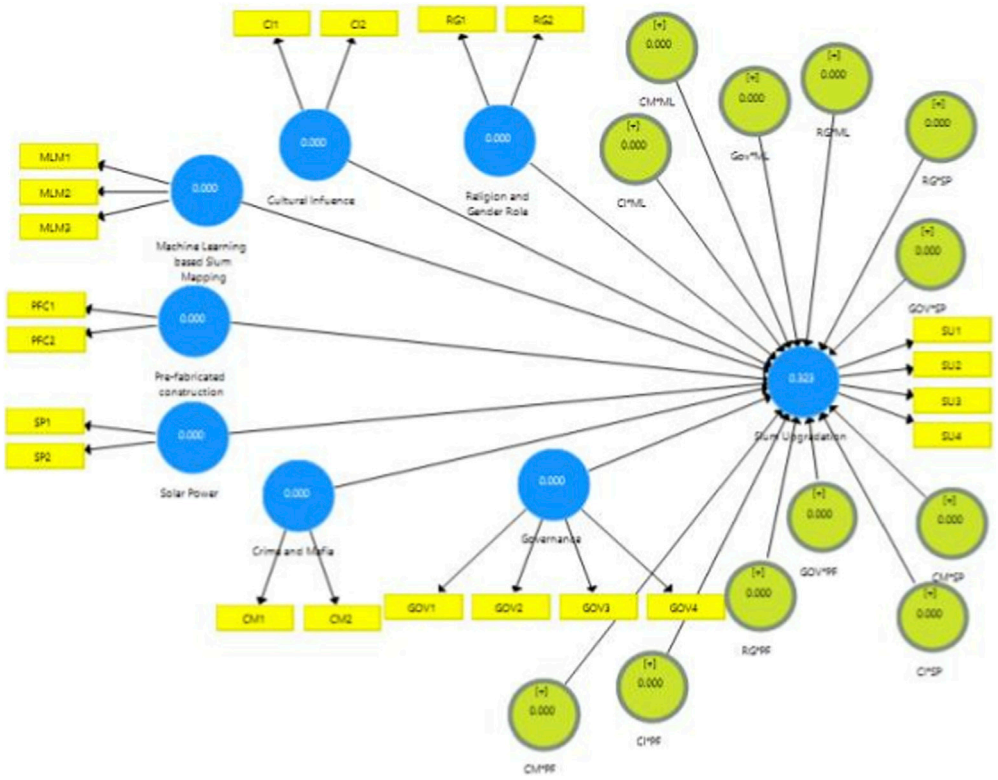


FIGURE 3
Blindfolding.

another important method that can help upgrade the slums in Islamabad. It has been analyzed that tighter spaces with prefabricated materials being designed by developers and architects around the world play an important role in increasing quality and reducing costs (Figure 3). The durability and strength of materials can be more precisely estimated by computer modeling (Gupta and Mukherjee, 2018). Thus, based on this information, the following hypotheses can be created:

H2: Use of solar technology has a significant impact on slum upgradation.

H3: Prefabricated construction has a significant impact on slum upgradation.

It is indubitable that the above-presented technological factors or tools can play a crucial role in upgrading the slums. However, it has been observed in various studies that the effects of these slum-upgrading strategies are moderated by upstream influences. In relation to this, it has been observed that upstream influences are considered a very important problem in Pakistan and, more specifically, in Islamabad, due to which the effects of slum upgrading strategies are being moderated (Richter and Georgiades, 2016; Sarwar, 2017). These upstream influences include crime and mafia influences, culture, religion, gender roles, and governance. It has been observed that a significant challenge to project implementation is presented by criminal organizations. For instance, access to water is controlled by the criminal mafia. Similarly, slum lands are acquired, developed, and sold by land mafias illegally (Turley et al., 2013). Therefore, criminal activities hinder slum improvement strategies and are considered an imperative barrier that hinders the progress of the government in upgrading slums in Islamabad. Based on this, the following hypothesis can be created:

H4: Upstream influences moderate the relationship between technological initiatives and slum upgradation.

3 Theoretical framework

There are various theories that encourage the use of technology or technology adoption, such as disruptive technology, social cognitive theory, rational choice theory, and technology acceptance models. However, considering the nature of the present study, the most important theory that can be used is the technology acceptance model. When it comes to this theory, it is considered an information system theory that models how technology can be used by users (Wu and Chen, 2017). However, it has been inferred that the role of behavior intention is imperative as it propels the users to adopt the technology. Moreover, the theory opines that the attitude of the user influences behavioral intentions, and this attitude is considered a general impression of the technology (Abdullah and Ward, 2016).

Based on the above theory, it is imperative for government officials, urban planners, and authorities to form a behavioral intention, which

TABLE 1 Reliability testing and convergent validity of the constructs.

Latent construct	Factor or outer loading	Cronbach alpha	Composite reliability		Average variance extracted (AVE)
Cultural influence	CI1	0.955	0.726	0.867	0.767
	CI2	0.788			
Crime and mafia	CM1	0.911	0.735	0.882	0.789
	CM2	0.864			
Governance	GOV1	0.850	0.893	0.924	0.753
	GOV2	0.854			
	GOV3	0.885			
	GOV4	0.881			
Machine learning-based slum mapping	MLM1	0.929	0.740	0.808	0.591
	MLM2	0.617			
	MLM3	0.775			
Prefabricated construction	PFC1	0.826	0.722	0.873	0.775
	PFC2	0.932			
Religion and gender roles	RG1	0.900	0.832	0.921	0.853
	RG2	0.947			
Solar power	SP1	0.946	0.859	0.934	0.876
	SP2	0.925			
Slum upgradation	SU1	0.786	0.868	0.910	0,716
	SU2	0.868			
	SU3	0.882			
	SU4	0.845			

*** indicates significance at 1%, 5%, and 10% confidence level.

plays a crucial role in leading to technology adoption. In addition, to support behavioral intention, a pro-technology attitude should be adopted (Anwar et al., 2017). Furthermore, this model suggests that two factors, such as perceived usefulness and perceived ease of use, affect the decision about the use of technology. Thus, it is important for the government to adopt the best possible technological initiatives to upgrade the slum and perceive the usefulness of the technology (Rana et al., 2016). In addition to this, sometimes the use of technology involves complications; therefore, it is important for the government to adopt such technology to upgrade slums that can easily operate. Therefore, to provide outcomes from the use of technology, it is imperative that there should be perceived usefulness and ease of use.

4 Conceptual framework

On the basis of the extensive review of previous literature, the key factors of technological initiatives and upstream influences have been identified. Based on the above framework, it can be comprehended that technology is an independent variable, which includes machine learning-based slum mapping. Machine learning is a sub-field of artificial intelligence that uses algorithms trained on data sets to create self-learning models that are capable of predicting outcomes and classifying information without human intervention. Machine learning is used today for a wide range of commercial purposes, including suggesting products to consumers based on their past purchases, predicting stock market fluctuations, and translating text from one language to another. In common usage, the terms "machine learning" and "artificial intelligence" are often used interchangeably with one another due to the prevalence of machine learning for AI purposes in the world today. However, the two terms are meaningfully distinct. While AI refers to the general attempt to create machines capable of human-like cognitive abilities, machine learning specifically refers to the use of algorithms and data sets to do so, and using machine learning with AI for slum mapping, as used in Indonesia, helps in coping with slum upgradation. Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV) cells or indirectly using concentrated solar power (CSP). PV cells convert light into electric current, while CSP systems use lenses or mirrors and solar tracking systems to focus sunlight on a hot spot, often to drive a steam turbine. Solar power is a renewable and clean source of energy that can help reduce greenhouse gas emissions and combat climate change, and prefabricated construction is a method of building that uses components made off-site in a factory and transported to the site to create a structure. It can reduce costs, time,

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TABLE 2 Discriminant validity testing using the HTMT ratio.

Crime and mafia		Culture influence	Governance machine learning-based slum mapping		Prefabricated construction	Religion and gender role	Slum upgradation
Cultural influence	0.371						
Governance	0.354	0.361					
Machine learning-based slum mapping	0.479	0.198	0.210				
Prefabricated construction	0.465	0.498	0.216	0.309			
Religion and gender role	0.597	0.627	0.275	0.294	0.671		
Slum upgradation	0.298	0.395	0.638	0.377	0.339	0.332	
Solar power	0.548	0.617	0.431	0.483	0.562	0.547	0.574

and labor and improve the quality and efficiency of construction. Prefabricated construction can be divided into different types, such as modular, panelized, or volumetric, depending on the size and shape of the prefabricated units, while slum upgradation is the dependent variable. There is a direct relationship between technology and slum upgradation. However, there is also a moderating variable, known as upstream influences, that moderates the relationship between technology and slum upgradation. There are four sub-variables of moderating variables: governance, crime and mafia, cultural influence, and religion and gender roles. Governance is the process of making and enforcing decisions within an organization or society. It involves decision-making, rule-setting, and enforcement mechanisms to guide the functioning of an organization or society. Governance can take different forms and levels depending on the type and scope of the entity that is governed, such as a state, a corporation, or a network. Governance can also have different goals and effects, such as promoting order, efficiency, accountability, or participation. Crime and mafia are two related topics that involve the activities and history of organized criminal groups, especially those of Italian or Sicilian origin. Crime is the violation of laws or norms that are established by a society or authority, and it can take various forms, such as violence, theft, fraud, or corruption. Mafia is a term that refers to a network of hierarchically structured crime families that operate outside the law and often control illegal businesses, such as gambling, drugs, or prostitution. Culture influence is the effect that a culture has on the thoughts, feelings, and behaviors of the people who belong to it or interact with it. Culture is a complex and dynamic system of shared beliefs, values, norms, and practices that shape how people perceive and respond to the world. Culture can influence various aspects of our lives, and religion and gender roles are two topics that are often intertwined and influence each other. Religion can shape the expectations and norms for how men and women should behave, relate, and contribute to society. Gender roles can also affect how people practice and experience their faith, as well as how they interpret and apply religious teachings to harmonize the society and practices used in slum development and also in the enhancement of the livelihood of the society This study aims to identify the impact of all the independent variables on slum upgradation, which is a process of improving the living conditions of people who reside in slums, which are informal settlements that lack basic services and infrastructure. Slum upgradation involves physical, social, economic, and environmental interventions that are carried out in collaboration with the slum dwellers, community groups, local authorities, and other stakeholders. In this manner, the association between technological initiatives and slum upgradation has been examined in this study. Moreover, the moderating effects of all the sub-variables of upstream influences have been examined on the association between technological initiatives and slum upgradation.

5 Methodology

5.1 Methods of data collection

As the researcher adopted a quantitative research design, there is numeric data collection in the study. All the data are accumulated by the researcher using the primary method of data collection, employing a questionnaire as the instrument. Therefore, in order to collect the data from the questionnaire, the target population includes the employees of

TABLE 3 Path analysis of the model.

Path	Path coefficient	T statistics	*p*-value
CI*ML - > Slum upgradation	−0.089	0.953	0.341
CI*PF - > Slum upgradation	0.091	1.293	0.196
CI*SP - > Slum upgradation	0.041	0.450	0.653
CM*ML - > Slum upgradation	0.026	0.330	0.742
CM*PF - > Slum upgradation	0.047	0.687	0.492
CM*SP - > Slum upgradation	−0.064	0.865	0.387
Crime and mafia - > Slum upgradation	−0.108*	1.709	0.088
Cultural influence - > Slum upgradation	0.082	1.202	0.230
GOV*PF - > Slum upgradation	−0.011	0.161	0.872
GOV*SP - > Slum upgradation	−0.025	0.358	0.721
GOV*ML - > Slum upgradation	−0.168**	2.243	0.025
Governance - > Slum upgradation	0.478***	9.760	0.000
Machine learning-based slum mapping - > Slum upgradation	0.296***	4.886	0.000
Prefabricated construction - > Slum upgradation	0.074	1.075	0.283
RG*ML - > Slum upgradation	0.144**	1.988	0.047
RG*PF - > Slum upgradation	−0.115	1.584	0.113
RG*SP - > Slum upgradation	0.008	0.089	0.929
Religion and Gender Role - > Slum upgradation	−0.022	0.302	0.763
Solar Power - > Slum upgradation	0.148**	2.191	0.029

***, significance at 1%; **, significance at 5%; *, significance at 10%.

TABLE 4 Model quality and predictive relevance.

	R-square (%)	R-square adjusted (%)	Q-square
Slum upgradation	51.57	48.20	0.323

TABLE 5 Summary of the research hypotheses.

Hypothesis statement	Decision
H1: Machine learning-based slum mapping has a significant impact on slum upgradation	Accepted
H2: The use of solar technology has a significant impact on slum upgradation	Accepted
H3: Prefabricated construction has a significant impact on slum upgradation	Rejected
H4: Upstream influences moderate the relationship between technological initiatives and slum upgradation	Accepted

the Pakistan Bureau of Statistics (PBS), urban planners from the Ministry of Public Works and Housing, and households in Islamabad. The reason for collecting the data from primary sources is that the data collected from these sources are much more accurate and authentic. The Pakistan Bureau of Statistics is one of the most prominent federal agencies of Pakistan that works under the government; it has been developed to offer national statistics services and offer comprehensive and solid statistical research. Therefore, the employees associated with the Pakistan Bureau of Statistics have been included in this research investigation, which enables the researcher to obtain the most relevant and factual data about the study. On the other hand, the urban planners belonging to the Ministry of Public Works and Housing and households in Islamabad were also included in the research investigation for the most reliable and valid data. Moreover, it had been ensured that all the study participants belonging to PBS must have had at least 4 years of experience so that they could provide some useful insights into the research topic.

In addition, primary data collection enables the researcher to obtain topic-specific insights (Heap and Waters, 2019). In addition

to this, there have been continuous changes in the number of slum settlements in Islamabad since 2020. Therefore, collecting data from secondary sources cannot provide up-to-date and recent insights. This is another reason that propelled the researcher to collect data from primary sources.

5.2 Sample size and techniques

The sample size that was taken for the purpose of the present study was 293. Out of 293 respondents, 123 are employees from PBS, 73 are urban planners, and the rest are from households. However, to obtain the sample size, the researcher used random sampling. There were a number of reasons that propelled the researcher to use purposive sampling. First, there was an equal chance provided to all, due to which there was more accuracy in the process of data collection. This was because there was a 50/50 opportunity provided to all. Second, it enabled the researcher to collect data conveniently and in a simple manner. The reason was that out of the population base, there are not enough basic skills required.

In addition, any classification error that could be involved in another form of data could also be removed by it. Lastly, there were very minimal chances of risk in performing data analysis because the sampling occurred within the specific boundaries. However, the exact population of the sample was not known for the determination of the sample; therefore, Herkenhoff and Fogli (2013) prescribed an infinite or unknown sample, which is presented below:

$$\mathrm{n} = \frac{Z^2 \times p \times (1-p)}{e^2}. \tag{1}$$

Based on the above formula, with a 1.95 value at a 95% confidence level, 'z' is the standard score. In addition, the proportion of the population that was intended to be captured in the study is 'p.' However, as the confidence level is 95%, it can be assumed that there are 5% chances of error. The below-presented value is the value that is obtained by inserting the values.

$$\mathrm{n} = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0\,05)^2} = 293 \text{ out of } 384. \tag{2}$$

Concerning this, it is recommended to have 384 respondents in the study; however, the likelihood of a low response rate was high, and this made the researcher reach more people. Therefore, the researcher approached approximately 400 respondents. Nonetheless, 293 eligible questionnaires were returned, which could be utilized for statistical testing. The response rate was computed to be 73.25%.

5.3 Research instrument

According to Patten (2016), the research instrument is considered a tool that is used for collecting research data. The type of research instrument used in studies is highly dependent on the type of data that needs to be collected, as there are different instruments used for collecting qualitative and quantitative data. As this research was based on a quantitative research design, the researcher used questionnaires based on closed-ended questions to collect the data. The questionnaires included all the important questions related to each of the independent, moderating, and dependent variables. In this manner, the association between all these variables was examined in this study. The type of questionnaire used in this study was a 5-point Likert scale that ranged from strongly agree to strongly disagree. Moreover, there is a self-administered questionnaire used by the researcher, and it is based on the English language. The key justification behind using a self-administered questionnaire in this study was associated with the lack of previous studies that examined the impact of technology on slum upgradation.

5.4 Data analysis

The data in the present study are analyzed via structural equation modeling (SEM), as the study is based on a quantitative research design. Partial least squares (PLS) is a technique that does not require distributing data normally (Hair et al., 2016). Furthermore, SmartPLS has been used to conduct the test. In the SEM technique, confirmatory factor analysis (CFA) and path assessment have been used in this study to analyze the collected data. The test of CFA has been conducted in this study to assess the reliability and validity of the model used in this study and test the internal consistency. On the other hand, a path assessment test has been conducted to examine the impact of all the variables of technological initiatives on slum upgradation. Moreover, the test of path assessment was also used to determine the moderating effect of the upstream influences on the association between technological initiatives and slum upgradation.

6 Results

6.1 Confirmatory factor analysis

The primary step toward the evaluation of the model using SEM is to examine the factors and the latent constructs in terms of reliability and construct validity. The research carried out by Avkiran and Ringle (2018) asserted that Cronbach's alpha and composite reliability are some of the most commonly used metrics to evaluate the reliability of latent constructs. In this regard, the research found that the values should be above 0.6 to deem a construct reliable, whereas a value above 0.7 is more appropriate. Considering this, the results presented in Table 1 show that all the latent constructs have high-reliability values. In terms of Cronbach's alpha, the least value is computed to be 0.722 for prefabricated construction, whereas in the context of composite reliability, the lowest value is computed to be 0.808 for machine learning-based slum mapping. Therefore, the reliability of the constructs is proven. In addition, the validity of the indicators is tested using factor or outer loading. Another research conducted by Hair et al. (2016) stated that the least acceptable value of factor loading is 0.6. In this regard, the values presented in Table 1 are all above 0.6; hence, no factor can be deemed invalid. In addition, the validity of the latent constructs is tested using AVE, and as stated by the research of Kline (2015), the values should be higher than 0.5. Therefore, it is evident from the results that all the values are found to be valid as they are above 0.5, implying the latent constructs to possess convergent validity. All the results detailed in this section can be viewed in Table 1.

In addition to convergent validity, where relatedness is evaluated, discriminant validity is also necessary (Kline, 2015). It

examines distinctiveness, and according to the study of Wong (2011), the HTMT ratio can be used for its evaluation in the SEM model, whose values should not surpass 0.85. Concerning this, the results presented in Table 2 depict that none of the values are found to be exceeding the prescribed threshold. Therefore, it can be asserted that discriminant validity is also found in the variables.

6.2 Path analysis of the hypothesized model

In this step, the researcher has conducted bootstrapping, where the technique of resampling is used for obtaining the significance level of the associations under consideration, as stated by Celek (2018). Following bootstrapping, the results obtained are presented in Table 3 in terms of path assessment. In accordance with the results obtained, the effect of crime and mafia is computed to be negatively significant [B = −0.108; p-value = 0.088 < 0.1]. This implies that crime and mafia prevailing in Islamabad hinder the upgradation process of the slums. It has been inferred based on the p-value and the coefficient value, which has a negative sign. Moreover, the moderating effect of governance is also computed to be negative, with machine learning as the independent construct [B = −0.168; p-value = 0.025 < 0.05]. In addition, the direct effect of governance on slum upgradation in the context of Islamabad is computed to be positive and significant [B = 368 .478; p-value = 0.00 < 0.01]. This entails the inference that improvement in the government can lead to enhancement in the upgradation of the slums in Islamabad. Contrarily, the direct effect of machine learning-based mapping of the slums is computed to be statistically significant and positive [B = 0.296; p-value = 0.00 < 0.01]. On the other hand, religion and gender roles are found to be moderating the relationship between machine learning-based mapping of the slums and their upgradation [B = 0.144; p-value = 0.047 < 0.05]. Lastly, the effect of solar power is also calculated to be statistically significant and positive [B = 0.148; p-value = 0.029 < 0.05]. However, all the other relationships and effects tested in Table 3 are computed to be statistically insignificant as their p-values are above 0.1. All the discussed results can be seen in Table 3.

One of the primary objectives of this study has been to determine the impact of technology on upgrading slums in Islamabad. Based on the results presented in the table, a significant impact of machine learning and solar power technology has been found on slum upgradation. However, as per the results of the path assessment, no significant association has been found between prefabricated construction and slum upgradation. Moreover, the study also aimed to identify the moderating effect of upstream influences on the association between technological initiatives and slum upgradation. In this regard, the significant moderating effect of governance, religion, and gender roles on the association between machine learning and slum upgradation has been found. Apart from that, all the other variables of upstream influences are found to have an insignificant moderating impact on technological initiatives and slum upgradation.

6.3 Model quality and predictive relevance

In this section, the quality of the model is tested using R-squared along with adjusted R-squared. The value of R-squared is computed to be 51.57%, which implies that the variance in the machine learning-based slum mapping, prefabricated construction, solar energy, moderation of gender and religion role, crime and mafia, governance, and cultural influence explain the 51.57% variance in the slum upgradation of Islamabad. Furthermore, after fixing the errors, the value is reduced to 48.20%. In terms of predictive relevance, the blindfolding technique has been used, which has helped in obtaining Q-square. According to the research of Esposito-Vinzi et al. (2010), the value of Q-square should be higher than 0. In this regard, the results presented in Table 4 indicate that the value is calculated to be 0.323, which is above 0. Therefore, the model of this study possesses predictive relevance.

6.4 Summary of the hypotheses

The hypotheses that were constructed in the initial sections of this paper have been summarized in this section. The summary is presented in Table 5, where it has been concluded that all hypotheses are accepted except for H3. This means that prefabricated construction does not affect slum upgradation in the context of Islamabad; however, upstream influence is found to have a significant moderation, especially in terms of governance, religion, and gender roles.

7 Discussion

This research was aimed to assess the impact of new technological initiatives on the upgradation of slums, and the moderating role of upstream influences was also examined in the context of Islamabad. The overall results of the path assessment in this study have provided clear and conclusive findings with respect to the association between all the key variables. First, the results of Cronbach's alpha and composite reliability confirm the reliability of all the latent constructs that were incorporated in the model. Moreover, the results of AVE and factor loading also confirm the validity of all the factors and constructs, as all the values fell under the standard threshold values. On the other hand, concerning the impact of technological initiatives on the upgradation of slums, the results of path analysis outline machine learning-based slum mapping and the use of solar technology as factors that have a direct and significant impact on slum upgradation. This is also found to be consistent with previous studies, in which the significant impact of solar energy and machine learning-based slum mapping on slum upgradation has been found (Baruah, 2010; Duque et al., 2017). However, the results of this study found no significant association between prefabricated construction and slum upgradation. Moreover, the overall outcomes of path analysis also confirm the significant moderating effect of upstream influences on the association between technology initiative and slum upgradation. In this regard, the variable of religion and gender roles is found to have a significant moderating effect on the association between machine learning-based slum mapping and the upgradation of slums, whereas governance is found to have a significant but negative moderating effect on machine learning-based slum mapping and slum upgradation. Apart from that, all the other moderating variables of upstream influences, including crime and mafia and cultural influences, have no significant moderating impact on the association between technological initiatives and slum upgradation. However, this primary finding contradicts the results of most of the previous research, in which cultural influences and crime and mafia were

recognized as the most influential factors of slum upgradation (Turleyet al., 2013; Sarwar, 2017). Lastly, the direct impact of crime and mafia is also found to have a significant but negative effect on slum upgradation. The overall findings of this study have made a valuable contribution to the existing body of literature, as there was a lack of evidence in the previous literature regarding the moderating role of upstream influences on the association between technology and slum upgradation in Islamabad. Conclusively, the findings of this study have confirmed the significant moderating impact of upstream influences on the association between technology and slum upgradation.

8 Conclusion and recommendations

The overall outcomes of this study highlighted the significance of technological initiatives in improving the upgradation of slums in Islamabad. The main aim of this research was to analyze the impact of technological initiatives on slum upgradation and examine the moderating effect of upstream influences on the association between technological initiatives and slum upgradation. In this regard, the variables of technological initiatives were assessed through three different factors: machine learning-based slum mapping, prefabricated construction, and the use of solar technology. On the other hand, the variable of upstream influences was examined through crime and mafia, cultural influences, governance, and religion and gender roles. As per the overall outcomes, machine learning-based slum mapping and the use of solar technology were found to have a significant impact on slum upgradation, whereas prefabricated construction has an insignificant impact on slum upgradation. Lastly, the findings also confirmed the significant moderating effect of upstream influences on the association between technology initiatives and slum upgradation. Based on the overall analysis, the following recommendations are proposed:

- ❖ It is important for the government to take strong action against crime and mafia, as it can negatively influence the effectiveness of technology initiatives for slum upgradation.
- ❖ Initiatives for slum upgradation such as a strong governance system with accountability, where rules and regulations are strictly followed, are required.
- ❖ It has also been suggested to use solar energy for the upgradation of slums, as it will help produce electricity for the large population living in them.

9 Limitations and future research direction

The overall scope of this research was limited to Islamabad, as all the data that have been collected and analyzed in this study were based on Islamabad. Thus, the findings of this research cannot be applied to any other context or region. In this regard, future researchers can consider expanding the scope of this study by adding more cities or covering the whole country. On the other hand, the researcher in this study has followed primary quantitative data, whereas qualitative and secondary data have not been incorporated in this study. Therefore, for future research, the same study can be carried out by incorporating a mixed research design and collecting the data from both secondary and primary sources. This will allow the researchers to provide more conclusive results by ensuring the validity and reliability of the research findings.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants or participants' legal guardians/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

MK: writing–original draft. KB: formal analysis and writing–review and editing. GA: formal analysis, software, writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fbuil.2024.1324954/full#supplementary-material

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