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EDITED BY
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Robert Home,
Anglia Ruskin University, United Kingdom

*CORRESPONDENCE
Gabriella Maselli
✉ gmaselli@unisannio.it

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A novel cost estimation model for the urban regeneration of a slum: the case of Kibera (Nairobi)

Antonio Nesticò[1], Federica Russo[1], Gabriella Maselli[2]* and Michele Vietri[1]

[1]Department of Civil Engineering, University of Salerno, Fisciano, Italy, [2]Department of Engineering, University of Sannio, Benevento, Italy

Today, about one billion people worldwide reside in slums and informal settlements, which show extreme poverty and social inequality. Implementing well-structured strategies and programmes to make these settlements safer and more sustainable for residents is a challenge for governments. Therefore, it is crucial to define models to accurately predict the costs of intervention and assess the economic feasibility of slum upgrading actions. The aim of this paper is first to define possible intervention scenarios for the informal city and then to characterise an innovative model for the rapid estimation of related construction costs. The model, based on a synthetic-comparative evaluation procedure, allows estimating the urban regeneration costs of a slum according to the intervention scenario, which is differentiated into minimal, barely satisfactory, and fully satisfactory levels. This provides economic actors and policy makers with the essential financial terms to determine the resources to be allocated to support slums. The model is applied to the case study of Kibera (Nairobi), one of the most challenged slums in the world. The results provide a measure of the transformation costs per capita. These costs turn out to be insignificant compared to the expected economic and social benefits in the long run.

KEYWORDS

slum, informal city, urban regeneration, economic model, cost estimation

1 Introduction

Informal settlements have now become a feature of the urban economy in developing countries (Sekhani et al., 2022). These are characterised by precarious living conditions, poor infrastructure, and inadequate basic services, are the most obvious expression of poverty and social and economic inequality on our planet. As cities expand and the urban population increases, the problem of slums becomes more and more pressing and requires concrete and sustainable solutions (Killemsetty and Patel, 2022; Khan et al., 2024). Slum dwellers, in fact, correspond to one in three inhabitants in urban areas, about one billion people, the equivalent of one sixth of the world's population [United Nations Development Programme (UNDP), 2010; UNStats, 2021]. Most of these inhabitants come from developing countries where the situation is even more unsustainable (Smit et al., 2017).

There are several reasons that contribute to the formation and persistence of slums: rapid population growth, migration from rural to urban areas, social and economic exclusions and the need to be located close to urban resources and opportunities and the inability of local authorities to meet the great demand for decent housing (Niva et al., 2019). In addition, accelerated and haphazard urbanisation continues to lead to the development of unplanned informal settlements, where people build makeshift dwellings with improvised materials and without permits (WHO Kobe Center, 2005; UN-Habitat, 2014a,b; Awasthi, 2021). This is especially a problem for developing countries whose governments and local authorities lack

the resources and capacity to manage such population growth and the continued expansion of urban areas (Majale, 2008; Trindade et al., 2021). In particular, 80% of informal settlements are concentrated in East and South Asia, Sub-Saharan Africa and Central and South Asia (Ghasempour, 2015). Indeed, the level of urbanisation across Africa is expected to reach 58 per cent by 2050, increasing the number of urban dwellers from 400 million in 2010 to 1.26 billion by 2050 (UN-Habitat, 2014a,b). In sub-Saharan Africa in 2018, 54 per cent of the urban population lived in informal settlements, considerably higher than the global average of 29 per cent (World Bank, 2020).

The phenomenon of slums, increasingly accentuated by the effects of the climate crisis, is one of the main contemporary challenges facing the world. This requires a long-term commitment by governments and local authorities to improve access to housing and basic services and to promote sustainable urban planning (Quaye et al., 2022; Khan et al., 2023). Urban regeneration programmes, investment in education and vocational training, promoting access to housing credit and developing resilient infrastructure are just some of the strategies that can help improve living conditions in slums (Chakraborty et al., 2015; Uddin, 2018; Cherunya et al., 2021). The multiple measures promoted as aid by governments have attempted to improve the living conditions of informal settlement dwellers, but this has not translated into an improvement in the living standards of the poor. In fact, the provision of subsidies to the poor has not resulted in better living standards, as they still survive on less than $1.90 per day (Simiyu et al., 2019).

Nsiah et al. (2021) suggest that promoting financial inclusion is a key strategy for alleviating poverty in sub-Saharan Africa; however, this goal is often challenging to accomplish. Muindi and Mutwiri (2021) highlight that many financial institutions impose strict conditions for accessing their services, such as high credit costs, the necessity of collateral, and measures to minimize default risks. As a result, financial institutions end up creating more opportunities for the wealthy, leaving the less privileged at risk because they are less likely to access these credit opportunities (Ochieng et al., 2023). Self-help groups have minimal collateral requirements, lower interest rates, better credit terms and client-centricity, resulting in relatively affordable financing for the poor. Although these studies have analysed various measures and strategies to increase financial inclusion by making financial services more available, achieving optimal financial inclusion among residents of informal settlements remains a challenge. The greatest concern of the poor relates to their ability to afford a financial service, not its availability (Simiyu et al., 2019). Therefore, measures to ensure the provision of sufficiently accessible financial services for the poor remain unresolved.

Another aspect to be taken into account is the active participation of local communities, which is also essential for developing long-term solutions that respect human rights and promote inclusive development, responding to the needs and requirements of local communities (Sanga et al., 2022; Ho et al., 2023). To date, the international community and non-governmental organisations (NGOs) play an important role in providing technical and economic support to address the problem of slums (Minnery et al., 2013; Meredith et al., 2021).

In this context, prior to exploring potential strategies and measures for accessing financial services, it is crucial to determine the resources required for urban regeneration initiatives aimed at enhancing the living conditions of slum communities.

Thus, the aim of this research is to define a model for expeditious estimation of construction costs regarding possible intervention scenarios aimed at slum regeneration. The model is intended as a specific decision support tool for the slum issue.

This study is structured as follows. Section 2 introduces the slum phenomenon and the different courses of action taken over the years to address this issue. Section 3 defines possible intervention scenarios for the urban regeneration of a slum. Section 4 characterises a model for expeditious estimation of intervention costs according to the scenarios outlined in the previous section. Section 5 describes the application of the estimation model for the urban regeneration of one of the world's largest informal settlements: Kibera, located in the city of Nairobi, Kenya. This is followed by an analysis and discussion of the results in Section 6.

The paper concludes with a discussion of the broad application potential of the proposed estimation approach, including in relation to important economic policy objectives concerning: urban regeneration, reduction of natural hazards, which are increasingly intensified by climate change, sustainable development of the poorest countries, and containment of migration flows. Considerations on the limitations of the model and research perspectives are then reported.

2 Socio-economic issues and strategies for the slum phenomenon

Slums are densely populated urban settlements characterised by the lack of legal housing security and extremely precarious living conditions. These communities often develop spontaneously and unregulated, on public or private land without the necessary government permits. While early definitions of 'slums' combined physical, spatial, social and even behavioral aspects of urban poverty, more recently a slum has been redefined by the United Nations Human Settlements Programme (UN-HABITAT) as 'a contiguous settlement in which inhabitants are characterised by inadequate housing and basic services' (UN-Habitat, 2003). Then in 2013, the United Nations (UN) included slums in the Millennium Development Goals as part of Goal 7 to ensure environmental sustainability. Specifically, Target 7.D highlights the need to "Achieve, by 2020, a significant improvement in the lives of at least 100 million slum dwellers" (United Nations, 2013). In 2003 in Nairobi, a meeting of the United Nations Group of Experts defined the characteristics of an informal settlement (UN-Habitat, 2003):

1. Precarious residency status if there is no documentation attesting to possession status and therefore protection against possible evictions;
2. Poor structural quality of housing when there is the presence of inadequate and non-permanent structures built in dangerous places;
3. Overcrowding involving the presence of more than three people per room of a minimum of 4 square metres;
4. Inadequate access to sufficient and affordable drinking water;
5. Inadequate access to toilets if there is no private toilet or many people using a public toilet.

Despite progress, there are still about 2 billion people in the world who do not have access to safely managed drinking water services. Of

these, 771 million people cannot even access basic drinking water services. People with poor access to drinking water services are concentrated in sub-Saharan Africa (World Bank, 2023).

The absence of basic services fosters unhealthy living conditions, contributing to the spread of diseases such as malaria and tuberculosis (Ezeh et al., 2017; Firdaus, 2012; McFarlane, 2008; Woo and Hee-Jung, 2020). This issue is further exacerbated by high levels of crime and violence. Inadequate security, insufficient police presence, and socio-economic inequality often create a breeding ground for instability and criminal activity (Veron, 2008; Parham, 2012). All this jeopardises the safety and well-being of people living in slums and can also have a negative impact on the stability of the city in general.

Moreover, these settlements are among the urban groups most vulnerable to natural hazards that will intensify due to climate change (Satterthwaite et al., 2018; Boateng and Adams, 2023). Slums are in areas that are particularly prone to landslides and flooding and often near power lines, railways, etc. (Parvin et al., 2013). This is compounded by the poor structural quality of the houses and the exclusion of slums from formally promoted climate protection plans only for urban areas (Butcher-Gollach, 2015; Núñez Collado and Wang, 2020; Hambrecht et al., 2022).

Nevertheless, slums are integral to the socio-economic growth of many cities in developing nations. They serve as the primary hubs for informal sector activities, encompassing micro and small businesses as well as cottage industries (Smit et al., 2017; Breuer and Friesen, 2023). Most poor urban dwellers operate within the informal sector, which, outside of existing regulatory frameworks, contributes significantly to job creation, local economic development, the urban economy and national growth (Majale, 2008).

In recent decades, several lines of action have been applied in response to the complex issue of informal settlements. First, in the 1970s, the policy adopted by governments included slum eradication, through evictions. Despite being a very costly and socially disruptive method, it is still practised in some countries (Rigon, 2022).

Another approach pioneered in the 1970s is the so-called 'site and service', which consists of providing urban plots to families displaced from slums so that they can build their own houses 'progressively'. This strategy was criticised by many who felt it left families generally worse off than they were in the original slums.

In the 1980s-1990s, an increased awareness of the sensitive issue promoted on-site redevelopment approaches through, for instance, the provision of basic urban services, the implementation of innovative land access practices, and innovative access to credit for the needs and requirements of slum communities (Benton, 1994; UN-Habitat, 2003). The main advantage of this approach is that it maintains residents' social networks and community cohesion while improving their living standards (Abdenur, 2009). Currently, in-situ slum upgrading is the main policy promoted internationally to address the problem of informal settlements (Gulyani and Bassett, 2007; Meredith et al., 2021).

The success of this approach has involved the implementation of a variety of programmes that have focused on freshwater provision (Hylton and Charles, 2018), drainage and electricity systems (Parkinson et al., 2007; De Bercegol and Monstadt, 2018), infrastructure and urban services (Isunju et al., 2011).

A key aspect of the slum redevelopment approach is the involvement of the community in the decision-making processes and implementation of the regeneration of their settlements to ensure appropriate interventions that respect the needs of citizens (Gulyani and Talukdar, 2008; Corburn and Hildebrand, 2015; Smit and Musango, 2015). Community cooperation is particularly important because slum households have the greatest potential interest in ensuring that the benefits of interventions are lasting (Werlin, 1999; Roy et al., 2014).

For instance, Yeboah et al. (2021) observed that redevelopment initiatives in Kensup, Kenya, and Prometropole, Brazil, fell short of expectations. These projects failed to adequately identify and address the diverse needs of residents, resulting in limited or no utilization of the implemented solutions. In contrast, the redevelopment efforts in Baan Mankong, Thailand, proved successful because they prioritized and respected the needs articulated by the community.

Urban slum upgrading is in line with Goal 11 of the Sustainable Development Goals (SDGs)—Sustainable Cities and Communities, which aims to make cities and human settlements inclusive, safe, resilient and sustainable. This goal focuses on the regeneration of poor neighbourhoods, ensuring access to adequate, safe and affordable housing and basic services for all. In addition, the New Urban Agenda (NUA) also promotes the improvement of living conditions for all by addressing the persistence of multiple forms of poverty, inequality, and environmental degradation, which represent significant obstacles to global sustainable development (Corburn and Sverdlik, 2017).

To date, also in line with these goals, many governments and international organisations have recognised the importance of tackling the phenomenon of slums and are implementing policies and programmes to provide a future for this large part of humanity.

3 Methodology

Improving slums is a global challenge that requires collective commitment and a long-term vision (Jones, 2017). Due to the conditions of poverty and degradation in which slum communities live, few interventions are needed to reach the minimum requirements set by UN-Habitat and to ensure decent living conditions.

The equitable provision of infrastructure is a fundamental prerequisite for improving the living conditions and livelihood opportunities of slum dwellers. Lack of infrastructure, in fact, is a constraint on the productivity of existing businesses, the establishment of new ones and is an obstacle for potential job opportunities (Gulyani and Bassett, 2010).

Moreover, it is clear that in order to fully improve the quality of life of these residents, both urban redevelopment interventions and initiatives that can enhance their economic and social conditions are needed (Rankey, 2018; Russo et al., 2023).

El-Maradny et al. (2020) argue that investing resources in slum upgrading interventions requires the definition of precise indications on which interventions are most effective. Due to the different methods and strategies of redevelopment interventions and the complications encountered in implementation, the evaluation of their effects can be complex. According to UN-Habitat (2014a,b), a slum household is a group of individuals living under one roof, lacking one or more of the following conditions: (i) access to drinking water in sufficient quantity—20 litres/person/day—at an affordable price (less than 10% of the total household income), available without extreme exertion (less than one hour of walking per day); (ii) improved sanitation, which translates into access to an excreta disposal system, in the form of private or public toilets shared with a reasonable

number of people (iii) sufficient living space, i.e., less than three persons per habitable room; (iv) structural quality/durability of housing, i.e., a house built in a non-hazardous location and with a permanent structure sufficiently adequate to protect its inhabitants from a possible dangerous situation; (v) security of tenure, which includes the right to effective protection by the state against arbitrary and illegal evictions.

In light of this and considering that reference is made to investments aimed at the regeneration of urban neighbourhoods that show high levels of decay and for which it is economically viable to provide for the demolition and reconstruction of existing housing, we define three possible intervention scenarios for in-situ slum upgrading:

1. Minimum level. It provides for interventions to meet the minimum requirements set by UN-Habitat (2014a,b), as described above: (i) access to potable water through the implementation of water distribution and collection systems; (ii) access to improved sanitation through the implementation of a sewage system; (iii) sufficient living space per person; (iv) durability and structural quality of housing. The issue of current and future ownership or possession of dwellings remains to be studied. The implementation of such a scenario requires: the preliminary analysis of the state of affairs of the slum in question; the identification of all critical issues that do not allow the achievement of UN-Habitat standards; the design of new housing sanitation services and/or the improvement of existing ones. Obviously, this is a complex process that requires both the involvement of multidisciplinary teams with full knowledge of the context under analysis and the participation of the entire community. The implementation of participatory approaches is essential to develop sustainable solutions that comply with human rights and encourage inclusive development, addressing the local communities' needs and demands.
2. Barely satisfactory level. It includes redevelopment interventions to improve the livability level of the slum. In addition to the interventions foreseen in level 1, there are: (i) reclamation of polluted areas; (ii) waste management; (iii) construction of road networks; (iv) construction of drainage networks; (v) construction of green infrastructure. At this second level, work is therefore carried out at a neighbourhood scale, i.e., extrinsic or zonal characteristics are affected in order to improve the liveability of informal settlements. Here, too, it is necessary to use participatory approaches and multidisciplinary expertise.
3. To a barely satisfactory level, the road network must be able to support the stormwater network during heavy rainfall. Recycling can only be one of the possible waste management practices that would also provide employment opportunities. For green infrastructure, techniques such as vertical farming, which require limited space, are favoured due to high population density.
4. Fully satisfactory level. In addition to the interventions already foreseen at level 2, this includes interventions useful for socio-economic improvements in response to the high poverty and lack of income that characterise the slums. Useful actions may include, for instance, (i) counselling to aspiring entrepreneurs to start and run their own businesses; (ii) organizing workshops to develop vocational and entrepreneurial skills; (iii) scholarships for technical education of students.

The minimum and the barely satisfactory level allow urban regeneration of the slum, i.e., the improvement of infrastructure and the existing urban environment. The fully satisfactory level, on the other hand, allows for broader urban regeneration, including socio-economic interventions with objectives of sustainable development, social inclusiveness and improved quality of life.

The aim is to estimate the costs to be incurred to finance the improvements needed to make the informal settlements liveable in the different intervention scenarios envisaged. To this end, a model is defined for the preliminary estimation of the relevant construction costs. Through the prediction of the monetary amount needed for the actual execution of the works, the model is also useful in the *ex-ante* evaluation of the economic feasibility of the investment (Maselli and Nesticò, 2021; Nesticò et al., 2022a,b). The application of the estimation algorithms requires at least the preliminary design of the works to be realised.

The construction cost of an asset is understood as the total of the costs that the contractor has to incur to produce it. The total construction cost C_{tot}, incurred by the developer, is given by the sum of the following cost items:

$$C_{tot} = CC + E_t + U + I \quad (1)$$

Where: CC indicates direct construction costs, i.e., the costs of materials, labour and equipment needed to complete the project; E_t is the Technical Expenses and includes costs related to technical design and preliminary studies; U represents the utility costs, i.e., costs for the installation and connection of utilities such as electricity, water, gas and sewerage; I indicates the interest on the financial capital and it covers the financial costs associated with borrowing money to finance construction, such as interest on the mortgage or loan.

The Construction Cost CC, in turn, is the sum of the Technical Construction Cost TCC, the General Expenses GE and the Constructor's Technical Profit CTP:

$$CC = TCC + GE + CTP \quad (2)$$

$$TCC = MT + L + FT \quad (3)$$

Specifically, TCC represents the technical cost of construction composed of the costs of materials for work (MT), labour (L) and freight and transport (FT). The cost of materials (MT) refers to the expenses for the purchase of all goods required for production. In addition to the cost of the material itself, loading/unloading and waste charges are included in this item. The cost of labour (L) represents the price paid to perform the work necessary for the construction of the building on site. It reflects the remuneration of the construction worker, according to his degree of specialisation, and is inclusive of social security and insurance charges. The cost of freight and transport (FT) refers to the price for the use of capital goods necessary for the implementation and proper execution of all site activities. This cost includes both the rental cost of machinery and the depreciation rate of own means.

It is estimated by reference to the cost per hour taken from price lists or market analyses.

GE indicates the overhead costs which are composed of indirect, variable and fixed costs: variable costs are independent of the work and linked to the opening of the construction site, such as the costs for setting up the construction site or the costs of safety; fixed costs, on the other hand, are independent of the construction site activity, such as financial charges or the costs for personnel employed.

CTP expresses the profit accruing to the builder, i.e., remuneration for the organisation of construction production and work phases, plus any risks associated with any increase in input costs or penalties for delays or problems in the work. In other words, this term is the sum of the following rates: the remuneration of the builder who manages the planning, procurement of materials, labour and logistics, also coordinating each phase of the construction process; a premium for the risk, both economic, linked to possible variations in costs, and technical, deriving from possible unforeseen events, variations during construction or even delays due to regulatory or logistical inefficiencies.

With reference to the intervention scenarios 1 and 2, outlined above, the CC construction costs of formulation (1) are explained:

$$CC_{(1)} = C_d \times S_b + CC_h \times S_h + \left(CC_w + CC_{ww}\right) \times S_w \quad (4)$$

$$CC_{(2)} = CC_{(1)} + CC_g \times S_h + CC_{dr} \times S_w + CC_r \times S_r \quad (5)$$

Respectively, for the minimal (1) and barely satisfactory (2) levels of intervention, each cost item represents:

- C_d – Technical demolition cost, generally expressed in units of currency [€, $ or other] per square metre or cubic metre of material to be demolished;
- CC_h – Technical construction cost of housing, expressed per square metre;
- CC_w – Technical construction cost of the water mains measured in linear metres;
- CC_{ww} – Technical cost of constructing the wastewater collection network, to be expressed in linear metres;
- CC_g – Technical construction cost of green infrastructure, in square metres;
- CC_{dr} – Technical cost of the drainage network measured in linear metres;
- CC_r – Technical construction cost of road networks expressed in square metres.

These cost items are multiplied by: the built-up area with precarious dwellings (S_b); the area for housing (S_h); the area for road networks (S_r); the area for water, drainage and sewage networks (S_w).

The fully satisfactory level of intervention (3) was not made explicit as no particular construction interventions are planned, rather actions to improve the socio-economic fabric of the slums.

Two procedures can be used to arrive at the assessment of construction costs: analytical and synthetic comparative. The choice of procedure considers the level of planning available, processing time and information requirements.

The analytical procedure requires the analysis of the process and the production factors that contribute to the realisation of the work. Through the elaboration of an estimated metric calculation, this procedure makes it possible to obtain the precise amount of resources required to carry out the intervention. Each item of the metric calculation corresponds to a unit cost that can be determined synthetically from the official price lists of each State or Region, or analytically through a price analysis. The latter consists in defining the components and their relative incidences necessary for the realisation of the work itself. This procedure is particularly useful in cases where the price list does not cover the work envisaged by the project or has very different characteristics. This implies the need for a definitive or executive reference project. Slums cover very large areas, almost equal to entire towns or villages, so it is very complex to apply the analytical procedure by drawing up a metric calculation for each civil work to be carried out.

The synthetic comparative procedure, on the other hand, makes it possible to arrive at a forecast of the construction cost of the work through direct comparison with the known costs of similar works already completed. This procedure, even through the use of a preliminary project, allows a construction cost estimate to be obtained in a summary manner, albeit with a lesser level of detail than the estimate obtained from an analytical procedure. For a highly unstable economic-political context such as that of the slums, this approach has limitations related to data retrieval and the costs of sample civil works: price lists are dated and difficult to find and costs do not always reflect official ones (Nesticò et al., 2022a,b). The steps involved in the process are:

1. Retrieval of data on unit cost items for civil works similar to those to be estimated;
2. Choice of a technical parameter to measure size for comparison with the sample civil work (number of rooms, volume, surface area, etc.);
3. Estimation of the overall reconstruction cost according to the technical parameter and the discounted unit cost.

The following Figure 1 explains the steps of the model and the procedures for estimating the economic terms.

4 Intervention costs for the urban regeneration of the Kibera slum (Nairobi)

As literature studies have shown (Section 2), urban regeneration interventions in slums improve the quality of existing settlements by making spaces healthier, safer, and more sustainable places for the entire population.

The expeditious construction cost estimation model, which is useful for defining the resources to be allocated for slum upgrades, is applied to the Kibera slum in the city of Nairobi. Described in several studies as the largest slum in Africa and among the largest in the world (Agayi and Serdaroğlu Sağ, 2020), Kibera stands out as a slum with unique characteristics in terms of poor housing conditions, overcrowding, lack of land security, inadequate drinking water and poor hygiene (Meredith et al., 2021). While most of the research conducted on the Kibera slum has focused on social, economic, environmental and spatial issues, no study, to the best of our knowledge, has addressed the issue of estimating the costs necessary

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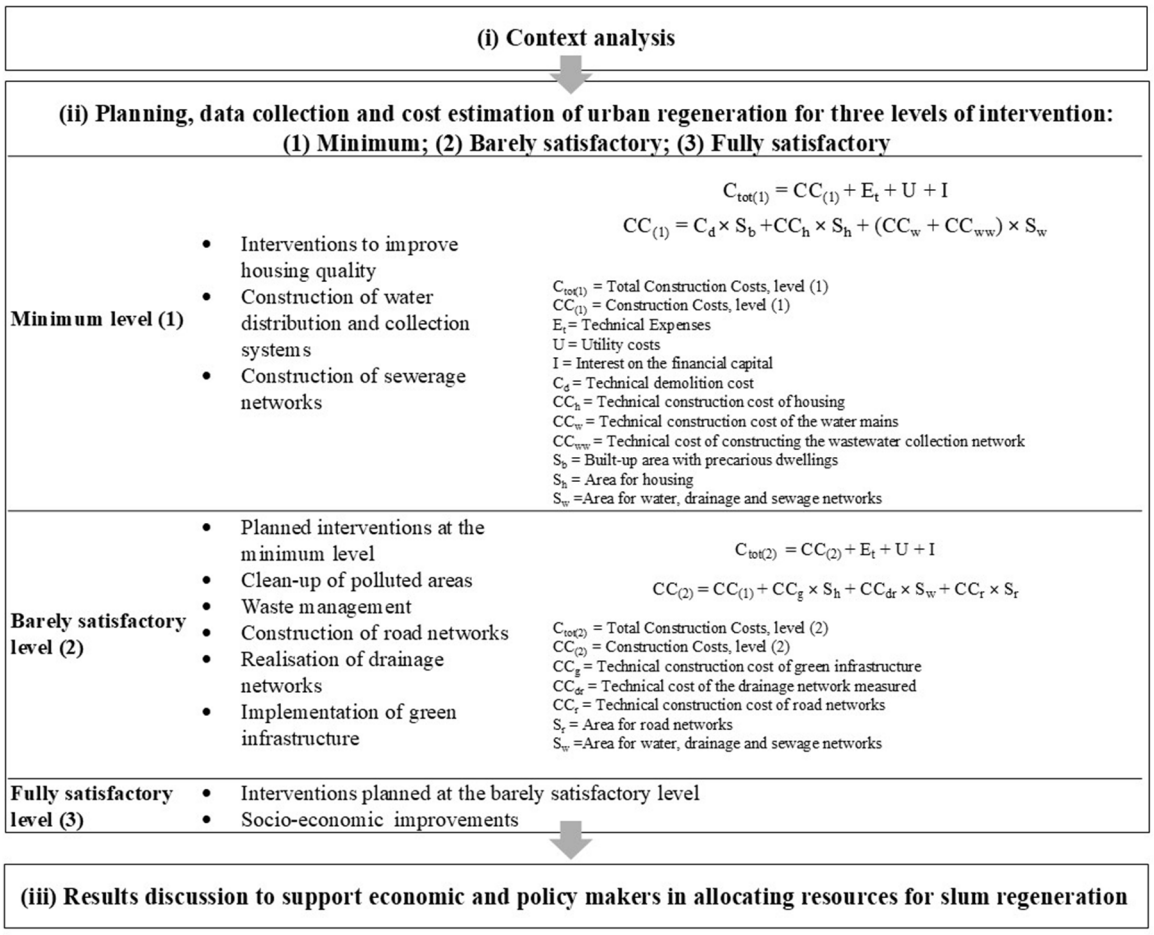

FIGURE 1
Model steps.

to implement urban regeneration interventions to achieve the minimum requirements set by UN-Habitat and to ensure decent living conditions, according to three different levels of acceptability: minimum, barely satisfactory and fully satisfactory.

For the cost estimation, extensive data collection was conducted both directly in the field by one of the authors and from official documents such as price lists, government reports, reports compiled by non-governmental organisations (NGOs) and academic research articles. The fieldwork was carried out continuously in October 2022 by one of the authors, who together with the non-profit organisation UCESCO collaborated on the construction of a school for the Kibera community. During this period, information and data were systematically collected from local and national government offices such as the Institute of Quantity Surveyors of Kenya, construction companies, technicians and professionals working in the area.

4.1 Study area investigation

The Kenyan capital since 1963, the year of the declaration of independence from the British Crown, Nairobi has seen an exponential growth in its population from about 500,000 in 1969 to 4,397,000 in 2019. By 2025, the population is expected to increase to about 5 million [Kenya National Bureau of Statistics (KNBS), 2020].

Moreover, due to rapid and unstoppable urban growth and the city's weak planning policy, there has been a proliferation of informal settlements throughout the urban area.

Among the most prominent are: Kibera, Mitumba, Mathare and Korogocho. According to Amnesty International's 2019 report, there are approximately 2 million people living in informal settlements in Nairobi, almost half of the urban population.

The Kibera slum, 5 km from Nairobi's Central Business District, originated after World War I, when the British colonial government decided to station 600 Nubian soldiers—Sudanese war veterans who had fought alongside the British—in the area as a form of reward for their military services. However, after Kenya's independence, the Nubians lost the right to the land they claimed. From then on, they and the immigrants who settled in the slum after 1963 were considered squatters, as they lacked title to the land, which had been declared state property (Bird et al., 2017).

The Kenyan government's lifting of restrictions on the movement of Africans immediately after independence in 1963 caused a sharp in-crease in internal migration from rural areas to

Nairobi, which had a significant impact on Kibera. Many people moved there because they saw Kibera as an area that was more economically accessible than other parts of the city, close to workplaces and perceived as relatively safe. In 1969, however, the legality of the settlements came into question when the Ministry of Lands declared Kibera a state property belonging to the Republic of Kenya (Smedt, 2011). Although the National Housing Policy, adopted by the government, provided for the evacuation of the slums and the construction of affordable housing (ROK, 2004), Kibera was not demolished, both to avoid a humanitarian crisis and for political and economic interests. This was because the government also considered informal settlements as an alternative solution to house the growing urban population, as the available affordable housing was insufficient (Smedt, 2011).

Kibera covers 2.38 km^2 making it one of the most densely populated areas of the city, and is divided into 13 villages that are uneven in terms of income levels, infrastructural development and ethnic composition. These are the villages of Kisumu Ndogo, Soweto East, Silanga, Makina, Mashimoni, Gatwekera, Kianda, Raila, Lindi, Gichinjio, Kiambi Muru, Laini Saba and Soweto West (Agayi and Serdaroğlu Sağ, 2020).

In 2008, the Map Kibera Project research group initiated a mapping project of Kibera with the aim of defining the physical characteristics of the settlement, such as topography, structures and infrastructure, and the socio-demographic dimensions of the local population. From this project, based on the data collected for one of the 12 villages that make up Kibera, Kianda, a population of between 235,000 and 270,000 people was estimated for the entire settlement, with a density of 95,000 people per km^2 (Marras, 2009, 2010, 2012). In Figure 2, the Map Kibera Project research team reported the area of Kibera and its component villages.

The average size of the shacks in Kibera is about 4 metres by 4 metres in which up to eight people often live. As with most slums, these dwellings are built using mud walls, earth or concrete floors and tin roofs, as shown in Figure 3.

Furthermore, only 20% of the slum has electricity. The percentage of housing served by drinking water is also very low. Until a few years ago, it was collected, non-potable, directly from the Nairobi dam. Even today, toilets are still lacking in much of Kibera and the same latrine is often shared by numerous shacks. These severe living conditions are the cause of numerous epidemics, especially of typhoid and cholera, which are very dangerous especially in the absence of government clinics and hospitals (Desgroppes and Taupin, 2011; Gallaher et al., 2013). Duflo et al. (2012) described the burden of disease resulting from the unhealthy living conditions in the slums: in Kibera, 16% of the interviewed households reported having at least one chronically ill family member in the three months prior to the interview.

In addition, the Kibera slum is severely exposed to flooding due to both the proximity of the Ngong River and its tributaries, and the problems of poor water drainage and solid waste management, as shown in Figure 4 (Marx et al., 2013; Mitra et al., 2017).

In recent years, several slum upgrading interventions have been implemented in Kibera. In 2004, the government of Kenya, in collaboration with UN-HABITAT and other stakeholders launched the Kenya Slum Upgrading Program (KENSUP), a project involving the three largest cities in Kenya, including Kibera, the largest slum in Nairobi. The programme's main goal is to improve the lives and livelihoods of communities living and working in slums through the construction of low-cost housing and the installation of social and physical infrastructure (Solymári et al., 2021). In the same year, the Kenyan government initiated the Nairobi Railway Relocation Action Plan, an ambitious project to relocate more than 10,000 people settled in the vicinity of the railway line, preventing its safe operation. The project ensures that the livelihoods of those affected are improved and safeguarded. Yet another initiative for the redevelopment of the Kibera slum is the one led by the National Youth Service (NYS) programme. This

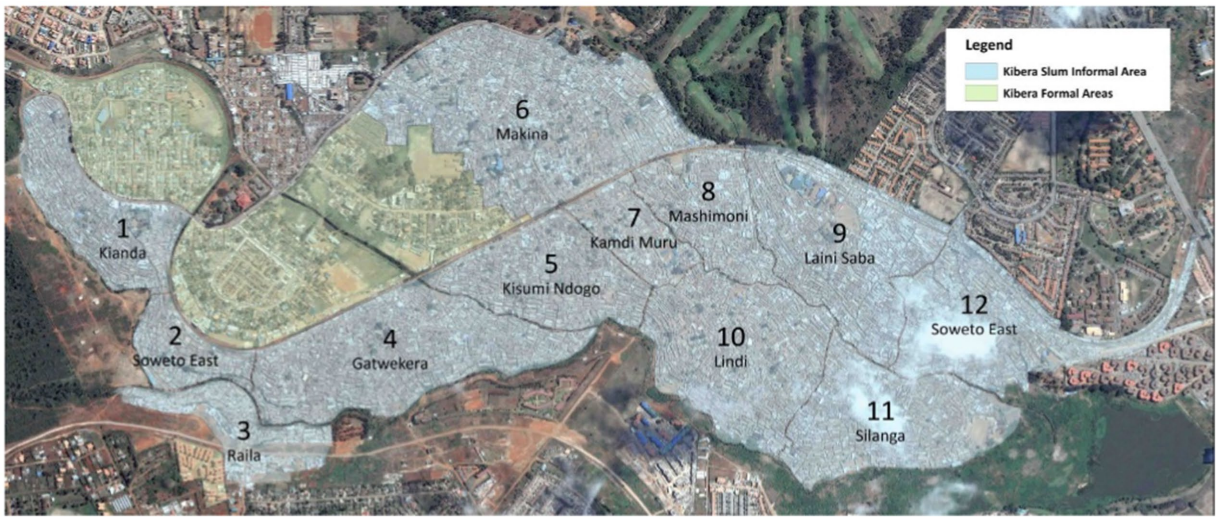

FIGURE 2
Top view of Kibera and distinction of its 12 villages. Source: Map Kibera Project (2023).

FIGURE 3
Examples of precarious dwellings built in Kibera with makeshift material found locally. Source: photos taken by one of the authors of the work (2022).

FIGURE 4
Representative image of unhealthy living conditions due especially to poor solid waste management. Source: Photos taken by one of the authors of the paper (2022).

initiative aims to improve the living standards and employment skills of young people through their involvement in society's economic activities (Mitra et al., 2017).

4.2 Model implementation

The development of the application sees the estimation of construction costs for two of the intervention scenarios described in Section 3:

- Minimum level, which includes interventions to meet the minimum requirements set by UN-Habitat;
- Barely satisfactory level, which includes interventions to improve the liveability level of the slum.

The individual items in the total construction cost equation are analysed according to the Equation 1.

To estimate the construction cost (CC) item, for both intervention scenarios, an initial demolition of the existing and inadequate dwellings is planned, with dismantling and possible material recovery (sheet metal, wood, stone, ect.) and then the construction of new dwellings and urban infrastructure. The Kenyan market is highly unstable, with highly variable prices due to very high inflation rates of about 7 percent in 2023 (Sumba et al., 2024). For this reason, construction costs are steadily rising. Therefore, all cost values were obtained by simultaneously examining both price list information and actual data provided by economic operators in the construction industry.

According to the Cost Handbook for construction works 2021/2022 by the Institute of Quantity Surveyors of Kenya (IQSK) (2021) the unit construction cost of a standard "simple low rise apartment block" is KES 36,810. The rates reported in the manual are obtained from market surveys and are inclusive of: (i) technical cost of construction (materials, labor, freight and transportation), (ii) taxes, (iii) overhead, and (iv) business profit. Expropriation costs are not considered, as the objective of the investments to be made is to upgrade living space and not to transfer property to new parties.

TABLE 1 Planned work and respective unit prices for the two intervention levels.

Manufacturing	Units of measurement	Unit price (KES)
Demolition costs		
Dismantling of a house with possible recovery of materials (sheet metal, wood, stone, etc.)	m^2	3,000
Construction costs for housing		
Building works for the construction of "Simple low rise apartment block." These buildings, usually up to four storeys, offer a comfortable balance between community living and personal space. They feature several residential units with shared facilities such as parking, laundry and recreational spaces. They cover an area of 50 to 120 m^2, with layouts of one to three bedrooms. Cost item excludes site works	m^2	36,810
Construction costs for infrastructure		
Construction of the water mains, including excavation, laying of the water mains, installation of manholes and subsequent backfilling of the excavation.	m	1,220
Construction of the wastewater collection network, including excavation, laying of the pipeline, installation of manholes and subsequent backfilling of the excavation.	m	4,220
Construction of the drainage network, including excavation of the concrete channel and installation of the perforated manhole cover to close the channel.	m	9,900
Construction of the road network, including lowering the existing carriageway and paving the road with concrete blocks or stone bricks.	m^2	2,250
Creation of green infrastructure, including construction of the wooden frame, subsequent laying of soil (expressed per square metre of living area).	m^2	1,255

To estimate the other cost items to be included in the model, direct market surveys were used, consulting, NGOs working in the field and technicians from government offices and local companies such as Integrum, a Kenyan construction project management company.

Table 1 shows the planned work for the two intervention levels under analysis and their respective unit prices. Unit cost items are multiplied by the corresponding intervention areas returned by the vector representation of Kibera by the Map Kibera Project research team shown in Figure 5.

The investment will be carried out in functional plots, with an additional plot close to the boundaries of the current slum. This is a plot with a area for housing of 0.04 km^2, which will accommodate the inhabitants who have temporarily lost their homes at the time of demolition. Given that the population of the city of Nairobi and of the Kibera slum itself is growing rapidly, once the redevelopment work is finished, the additional lot will be made available to inhabitants who need to better their living conditions, so that human rights are respected for all.

The inferred dimensional data are:

(i) built-up area = S_b = 1.43 km^2;
(ii) road surface = Sr. = 0.72 km^2;
(iii) length of the existing road network = S_w = 70 km

For new construction, according to the National Planning and Building Authority of Kenya in The National Building Code (2022), the minimum area for single room occupancy is 7 m^2 per inhabitant. Therefore, given a population of 250,000, the minimum floor area is equal to 1,750,000 m^2. Adding to this area the area occupied by the additional lot (40,000 m_2), S_h = 1,790,000 m^2.

The technical expenses (E_t) are derived from estimates by Integrum, a construction project management company in Kenya, which for the city of Nairobi predicts values ranging from 15 percent to 25 percent of the construction project capital. An average value of 20% of construction costs is assumed for the application case.

The same company also provides guidance on fees for construction permits and building plan approval (F_{ct}) charges required by the National Construction Authority of Kenya, an organization that regulates the construction industry. These charges vary according to the total project cost and for construction projects worth less than KES 5 million are zero. For construction projects with a value of more than KES 5 million, urbanization charges are calculated as 0.5 percent of the total amount.[1]

Finally, for interest on financial capital (I), the International Development Association (IDA) is assumed to be the investor entity of the intervention. The IDA is a World Bank-affiliated organization dedicated to providing aid to developing countries. In 2008, Kenya Vision 2030, the development program that aims to transform Kenya into a newly industrialized middle-income country by providing a high quality of life for all its citizens by 2030 in a healthy and safe environment, was approved. To this end, IDA is funding four World Bank programs: the Kenya Urban Support Program (KUSP), the Nairobi Metropolitan Services Improvement Project (NAMSIP), the Kenya Devolution Support Program (KDSP), and the Kenya Informal Settlements Improvement Project (KISIP). IDA funding is supported by contributions from member states of advanced economies and grants aid, called credits, to some 80 countries on very flexible and concessional terms. These credits have a term of 35–40 years with 10 years of grace period. They are interest-free and carry only a fee (service charge) of 0.75 percent on the total loan amount. For these reasons I = 0.75% of the Loan Principal is assumed in the application.

1 https://integrum.co.ke/construction-kenya-faqs-653/

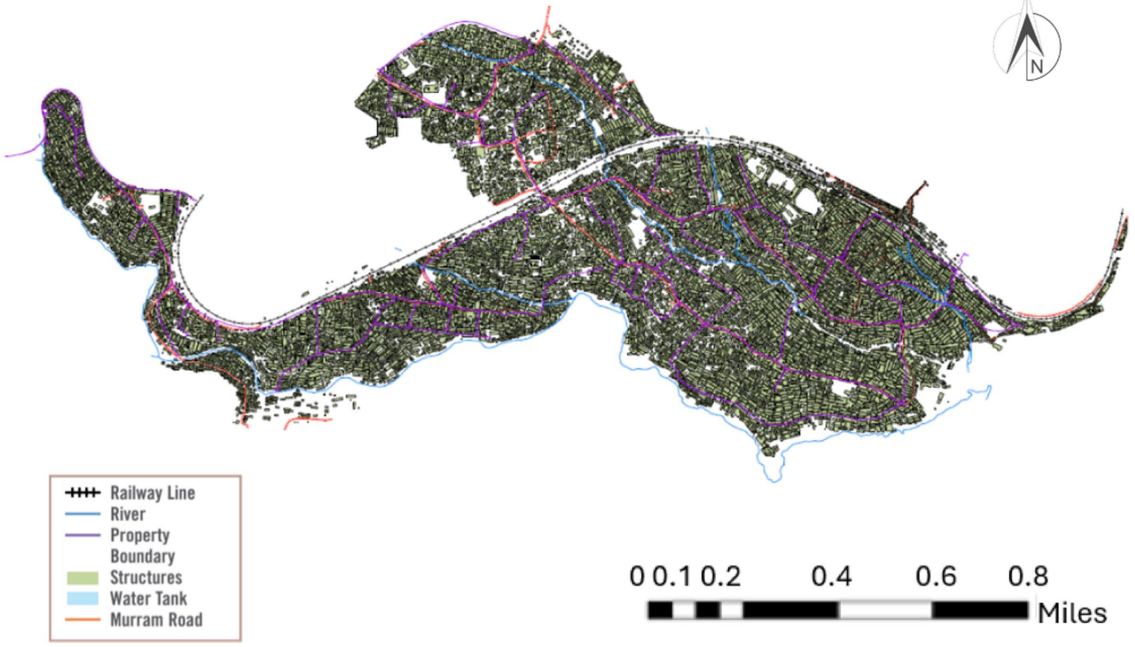

FIGURE 5
Kibera structure. Source: Map Kibera Project (https://mapkiberaproject.yolasite.com/maps-and-statistics.php).

TABLE 2 Total construction costs, per km² and per inhabitant for the two levels.

Intervention	Total construction cost	Construction cost per km²	Construction cost per inhabitant
Minimum level	85,663,335,826 KES 602,110,315€	35,992,998,246 KES/km² 252,987,527€/km²	342,0.653 KES/ab 2,408 €/ab
Barely satisfactory level	91,198,679,106 KES 641,017,127€	38,318,772,733 KES/km² 269,334,927€/km²	364,795 KES/ab 2,564 €/ab

The basic assumptions and data collected allow estimating the total construction cost for the two intervention scenarios. Applying Equations 4, 5 expressed in Section 3, the results obtained are:

Minimum level

From Equation 4:

$3{,}000 \times 1.43 \times 10^6 + 36{,}810 \times 1{,}790{,}000 + (1{,}220 + 4{,}220) \times 70 \times 10^3 = 70{,}560{,}070{,}000$ KES.

From Equation 1:

$[70{,}560{,}070{,}000 \times (1 + 0.20 + 0.005)] \times 1.0075 = 85{,}663{,}335{,}826$ KES.

Barely satisfactory level

From Equation 5:

$70{,}560{,}070{,}000 + 1{,}255 \times 1{,}790{,}000 + 9{,}900 \times 70 \times 10^3 + 2{,}250 \times 0.72 \times 10^6 = 75{,}120{,}015{,}000$ KES.

From Equation 1:

$[75{,}120{,}015{,}000 \times (1 + 0.20 + 0.005)] \times 1.0075 = 91{,}198{,}679{,}106$ KES.

The results obtained are summarized in Table 2.

5 Discussion

The data in Table 2 indicate a construction cost per inhabitant of 2,408 euros for the minimum level of intervention, i.e., to meet the minimum requirements set by UN-Habitat (Section 2). Once these requirements are met, the urban settlement can no longer be defined as an informal settlement.

To take the urban settlement to the second level, i.e., the 'barely satisfactory' level, the construction cost increases by approximately 7%, so that the cost per inhabitant is € 2,564.

The difference between the first and second level is therefore small, noting that the most expensive interventions are at the first level.

All in all, with an upgrading intervention costing around €2,000 per person, the benefits are manifold:

- Slum upgrading can lead to substantial improvements in community housing conditions by reducing overcrowding, improving access to clean water, electricity, sanitation, and road infrastructure;
- In terms of public health, interventions under the assumed scenarios, involving access to clean water and sanitation, reduce the spread of disease;
- The construction of new infrastructure can generate new job opportunities in the area, reducing unemployment and poverty and promoting greater social inclusion;
- Encouraging collaboration among residents and community involvement helps develop a greater sense of belonging and mutual trust.

The outcomes are constrained by the challenges inherent to the slum context, characterized by significant economic and political instability. This instability leads to considerable fluctuations in the unit prices used as reference points for estimates.

6 Conclusion

According to the findings of the World Cities Report, as of today there are about 1.6 billion people living in inadequate housing, about 1 billion of whom reside in slums (UN-Habitat, 2022). The emergency is global and, in the absence of appropriate intervention measures, is set to grow in size. The proliferation of these informed settlements, especially prevalent in the cities of developing countries, is the result of market and public policy failure for a large segment of the urban population (Wekesa et al., 2011). In fact, today's administrations are unable to ensure appropriate solutions for the ever-increasing demand for education, health, transportation and other essential services. In these realities, the state is often absent and most of the projects implemented are possible thanks to foreign funding, particularly from NGOs (Mutisya and Yarime, 2011).

Due to the conditions of great poverty and degradation in which slum dwellers live, the minimum requirements set by UN-Habitat (Section 2) would be achieved even with a limited number of interventions capable of ensuring at least decent living conditions. Urban regeneration interventions are, in fact, a viable solution for improving the living conditions of people living in these areas; however, they can be complex and costly and require careful planning and a multidisciplinary approach involving different stakeholders (Corburn and Hildebrand, 2015).

With the aim of providing a decision support tool and quantifying the resources to be allocated to urban slum upgrading, the document first defines three possible intervention scenarios: minimal; barely satisfactory; fully satisfactory. An innovative model for expeditious estimation of intervention costs through a synthetic-comparative procedure is then characterized. As is always the case, the reliability of the model is affected by the greater or lesser difficulty in obtaining data, and in the analyses under consideration also by the conditions of political-economic instability that may require continuous updates of the estimates. Nevertheless, the structure of the economic analysis model appears robust and useful for estimating in advance and with sufficient approximation the economic resources to be set aside to financially support slum regeneration interventions.

The estimation model characterized in Section 3 was applied to the case study of Kibera, one of the slums with the most critical issues and challenges to address located in the city of Nairobi. With reference to the two intervention scenarios analyzed, covering an area covering 2.38 km^2, the total investments in the year 2023 range from €602,110,315for the minimum level to €641,017,127for the barely satisfactory level. In terms of km^2, the amounts range from 252,987,527 €/km^2 for the minimum level to 269,334,927€/km^2 for the barely satisfactory level.

Considering also that the slum's resident population is estimated at 250,000, the analysis yields a minimum intervention cost of approximately € 2,408 per capita, a derisory figure when compared to Western living standards.

The proposed estimation model makes it possible to predict the magnitude of slum upgrading costs, which is of paramount importance for support to local authorities, government agencies, and NGOs to plan and allocate resources appropriately. This allows sustainable and targeted interventions to be planned, avoiding wastage of resources. In addition, knowing the extent of resources needed for redevelopment interventions helps in seeking funding and donations from investors and supporters.

Limitations of the model are attributable to a preliminary design basis. By improving the design level, analytical estimates can also be implemented for effect, with improved predictive reliability.

It is also clear that urban redevelopment interventions alone are not enough to improve the overall quality of life of slum dwellers as it is also necessary to intervene on economic and social aspects. In this sense, there are different economic policy actions that are proposed to address the issue of slums: (i) offer training and skills development programs to improve people's employability by helping them find jobs or set up their own businesses; (ii) make sure that children in slums have access to quality basic education, including adult literacy programs; (iii) offer financial services to slum communities to stimulate local economic activity and enable residents to start small businesses; (iv) provide access to small loans to people in slum communities to enable them to start economic activities; and (v) work with the private sector through public-private partnerships to develop slum regeneration projects that can create jobs and community services. Such Economic Policy actions should be part of an integrated approach that addresses social and economic challenges in slums in a comprehensive way. As shown by Frediani et al. (2023), equitable access to adequate housing in informal settlements can generate a direct economic growth impact of 10.5%, measured as gross national income (GNI) or gross domestic product (GDP) per capita. it is evident that this increase in the size of the economy and living standards in informal settlements is greater than the cost of ensuring adequate housing in many countries. In terms of health, life expectancy could increase by up to 4%, adding 2.4 years of life on average worldwide just through the direct effect of ensuring access to adequate housing in informal settlements. Finally, in terms of education, the expected years of schooling in some countries could increase by up to 28% due to access to adequate housing in informal settlements.

Research prospects involve estimating the costs required for actions aimed at ensuring socioeconomic improvements to communities as well. A further aspect that can be investigated is the economic quantification of the innumerable benefits associated with such interventions, such as reductions in disease and mortality rates.

Data availability statement

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

Author contributions

AN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. FR: Data curation, Formal analysis, Investigation,

Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. GM: Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. MV: Data curation, Investigation, Resources, Software, Writing – review & editing.

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