ORIGINAL RESEARCH ARTICLE

Assessment of the outcomes of innovative construction technologies in slum upgrading: A case of Mathare Valley, Nairobi

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ABSTRACT

Affordable housing was one of the four pillars of Kenya's big four agenda of 2018. Rapid rural-urban migration and the high cost of formal housing units have led to the proliferation of informal settlements commonly referred to as slums. Provision of decent housing is still a challenge in Kenya due to continuous population growth and high demand for low cost housing. The aim of this paper was to assess the outcomes of innovative construction in housing in slum upgrading in Mathare valley. Post-occupancy survey approach was used to establish existing technological challenges on the walls, roof and floors of the upgraded units. Structured questionnaires were administered to the slum residents. Descriptive statistics were used to analyze data and results were presented in tables. Results indicated that the upgrade improved the houses structural envelope of walls, floors and roofs. The respondent's perception of the scheme in terms of quality and acceptability was significant though deterioration of the structural envelope with time was evident. The upgrade improved the physical infrastructure and livelihoods as compared to the previous situation characterized by poor sanitation, degradable roofs, and walls and inadequate of social amenities. The relationships between residents were improved as compared to the previous situation. Better communal facilities such as roads, drainage and toilets were realized. The previous houses were made of assorted degradable materials which were substituted with fairly permanent elements during the upgrade. In conclusion, innovative construction technologies improved the social, economic and physical aspects of the project but certain aspects remained unchanged. The innovative construction method should focus on pro-poor approaches like improvement of the existing structures in lieu of demolition. The residents should be involved in assessing and determining their needs to ensure construction of houses suits their interests. Effective monitoring is critical to avoid displacement and minimize political interference and corruption.

Keywords: Innovation; Construction Technologies; Outcomes; Slum Upgrading

1.0 Introduction

The high cost of land and construction materials coupled by lack of financing has made the provision of affordable housing a challenge especially in the developing world. This challenge

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is complicated by a sharp increase in demand for shelter due to rural-urban migration. Housing is a component of human rights as outlined in the Universal Declaration of Human Rights (Assembly, 1948). Subsequent declarations and covenants such as the 1992 earth's summit in Rio (Brazil) have upheld the need for everyone to access decent and affordable housing. The housing blue print on sustainable construction was inaugurated under agenda 21 and the habitat agenda. Although slow, the blue print has seen some innovations in the construction industry.

Innovation is at the heart of the modern knowledge-based economy. Its contribution to economic growth, competitiveness, and higher living standards enables individuals and organizations to successfully exploit new ideas, products, and processes. Some of the major challenges facing the construction industry are the need to reduce the cost of construction, meet the rising demands for buildings by providing dwellings which are socially acceptable, economically sustainable, and environmentally friendly. Innovative practices that focus on the products and processes used in construction, therefore, need to be employed as much as possible (Freitas, 2007).

Effective innovation in construction is encouraged as it contributes to development of alternative building materials, processes and designs that enable reduction of construction costs and in effect promote provision of low-cost housing (David, 2014). Product innovation (changes in the products, services, or approaches that a construction organization employs) and process innovation (changes in how those products, services, or approaches are created and delivered) are two of the forms in which low-cost housing can be innovated. Fundi, Kaluli, Maritim, and Kabubo (2014) observed that municipal solid waste ash can be utilized to improve compressive strength of earthen bricks and walls.

Kenya, just like other developing nations, is faced with the need for better housing facilities for low income groups. David (2014) acknowledges that in order to meet the accelerating demand for housing, and to improve the living conditions in informal settlements, various organizations have been involved in using innovative practices in slum upgrading projects. In Kenya, building materials form almost 70% of the total cost of construction. It is, therefore, prudent that innovative cheaper practices focus on building materials such as stabilized earth blocks, sisal cement roofing sheets and rammed earth floors and their performance and consequences as relates to the social and economic impact. Currently the Kenya government produces approximately 50,000 dwelling units per year as compared to the demanded 250,000 units (Namayi, 2016). Affordable housing was the fourth pillar in the Kenya government economic recovery agenda of 2018. The beneficiary target groups were government employees and other people formally employed who can afford credit or mortgages. The informal settlement dwellers are often left out of the government housing opportunities due to their low incomes and lack of formal or permanent employment. These people can only afford accommodation in slums.

Some government housing interventions in Nairobi have made use of innovative construction materials and techniques like stabilized soil blocks and cement sisal roofing sheets in Mathare

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slum upgrading project. The project was sponsored by the German government through the Catholic Church. The government approved the construction, provided machines for soil blocks production, as well as suggested construction methods and quality controls (Namayi, 2016). These interventions were characterized by various innovative construction technologies but their physical and socioeconomic impacts are inadequately documented.

Provision of decent housing is still a challenge in Kenya due to the continuous population growth and demand for low cost housing that cannot be effectively addressed by the current conventional construction methods. The use of the innovative materials in slum upgrading projects has exhibited post occupancy challenges such as physical deterioration. The deterioration leads to increased maintenance costs and loss of the functional performance capacity and potential (Mwangi, 2013). A significant negative consequence of slum upgrading has been the fear of displacement among residents. This is due to worries that the upgraded housing would be unaffordable, and that corruption would affect unit allocation (Huchzermeyer, 2008). The increased innovative construction practices have inspired extensive research on sustainability, quality and safety of the built environment. Good built environment motivates a desirable distribution of pedestrian in public spaces promoting integration, proper land use, and connectivity (Makworo, Moirongo, & Mireri, 2013). It is against this background that this study sought to assess the impacts of innovative construction in housing in slum upgrading in Mathare valley. The lessons learnt can significantly contribute to improvement of the sustainability, quality and safety of innovative construction materials and techniques used.

This study on upgraded Mathare valley slum assessed the outcomes and socioeconomic impacts that are associated with the use of innovative construction technologies. The study sought to fill the gap of knowledge on the impacts of innovative construction technologies on low cost housing which is lacking on most of the research work literature. The aim of the study was to assess the socioeconomic influences of innovative construction technology with a view of guiding the planning of low-cost housing provision. The purpose of the study was to highlight how innovative construction technologies impacted the socio-economic aspects in slum upgrading.

2.0 Methodology

In Nairobi, the main upgraded slums include Mathare, Kibera, Pumwani, Korogocho, and Majengo. Mathare valley was the most prominent in terms of scope, planning and structuring. It involved the Kenya government, the Catholic archdiocese of Nairobi under Amani trust and Kreditanstalt für Wiederaufbau (KfW), donors from Germany. Mathare slum is on approximately ten-acre land and has thirteen villages namely: Kosovo, Gitathuru, Village 2, Mashimoni, Mabatini, No. 10, Kiamutysia, Kwa Kariuki, 4A and B, 3A, B and C. innovative construction materials such as Stabilized Soil Blocks and cement sisal fiber roofing sheets were significantly used in Village 4A and hence the justification of the study area.

This was a post upgrade occupancy evaluation that assessed users' opinion about upgraded buildings in Mathare Valley Slum. It used primary data collected from the field which was live feedback from the target slum population. The research adopted descriptive survey research

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design that allowed the researcher to have the residents of Mathare Valley explain or describe certain issues about innovative housing technologies that enabled the associations between variables to be established.

The target population for this survey was the entire Mathare Area 4A residents where slum upgrading project took place. Approximately 20,733 households were targeted for upgrading to better living conditions, and from this population, the study selected a sample to make inferences.

Simple random sampling procedure was used to select a sample representative of the target population. This method ensured that a fair chance was accorded to all members of the target population to participate. To capture a representative sample, data was collected at varying times of the day including late evenings and weekends to capture possible working household heads that would not be available during normal day times. Owners of the houses which exhibited innovative construction technologies by observation were targeted. Questionnaire administration to the slum residents were mainly conducted at the front of the houses and lasted for an average of 30 minutes by which the structured questionnaires were administered.

The Fishers (1992) formula was used to determine the appropriate sample size of the study assuming 95% desired level of confidence which was equivalent to standardized normal deviation value of 1.96 and an acceptable margin of error of 5% (standard value of 0.05).

$$n = Z^2pq/d^2$$

Where:
n = the desired sample size (if target population is large)
z = the standard normal deviate at the required confidence level.
P = the proportion in the target population estimated to have characteristic being measured.
q = 1-p
d = the level of statistical significance set.

Assuming 50% of the population have the characteristics being measured, q=1-0.5. Assuming we desire accuracy at 0.05 level. The Z-statistic is 1.96 at this level, therefore,

$$n = \frac{0.5^2 * 0.5^2}{0.05^2} = 384.$$

The sample size for the study was a total of 384 household heads from Mathare Valley slum. The study collected primary data using both open and closed-ended questionnaires where the questions were structured according to the study objectives to capture the main themes under study. A total of 384 questionnaires were administered to the household heads at random to those who benefited from Mathare Slum Upgrading projects. The respondents had the opportunity to express their views as regards positive and negative change and or experience due to the upgrade, community bond, experienced changes in the neighborhood, aspects of

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satisfaction regarding the dwellings construction components, maintenance costs and other associated aspects. During fieldwork, several observations were made. The researcher managed to enter several houses and documented the observed status of the upgraded slums. After receiving completed questionnaires, the data collected were checked for errors, omissions, exaggerations, and bias. Statistical Package for Social Sciences (SPSS) was used to analyze the data. MS-Excel 2007 was used to record the data for easier management and longevity. Each piece of information was entered after effective coding. Afterward, the data were analyzed based on the study's objectives. Checking of inconsistencies, anomalies, missing values, outliers (say data cleaning) was done in SPSS syntax. This was a descriptive study (Henning, Van Rensburg, & Smit, 2004). Descriptive statistics aimed at identifying the pattern of the data and consistency of the responses in each of the hypothesized impacts of innovation construction materials.

The researcher adhered to ethical research behavior by: Seeking permission from relevant authorities to carry out the research, assuring respondents of confidentiality and privacy of data collected and upholding that confidentiality, seeking informed consent for participation in the study, assuring respondents that the results of the study were only used for academic research purpose and avoiding research plagiarism and fraud. Iphofen (2016) views research ethics as the appropriateness behavior in relation to the rights of the subjects of one's study or those affected by it. The research ethics are inevitably affected by the broader social norms of behavior.

3.0 Results and discussions

The majority of respondents (81.1%) in the study felt that the slum upgrading process using the innovative walls, floor and roofing materials improved the houses to some extent. The positive perception can be attributed to the fact that before the upgrading process, the residents were largely tenants and therefore had to part with relatively high amount of rent to occupy the houses. The project reclaimed the land from the former landlords, since it was government land, and compensated the absentee owners for the homes on the land. With this property, the Catholic Archdiocese then upgraded the infrastructure and created a non-profit housing system where the residents paid a fair amount of rent over a period of time (7 Years) to own the houses.

Table 1: Perception on Improvement of Houses after Upgrade Process

Comparison	**Frequency**	**Percent**
Improved for the better	263	81.1
Remained the same	61	18.9
Total	**324**	**100.0**

There was a misperception that many slum dwellers only wanted to become homeowners as expressed by 61.9% of residents who indicated there were no minimum and maximum rent rates for different cadres of slum dwellers. These findings are consistent with UN-HABITAT's (2008) finding that during the upgrading of the slum, a lack of attention was paid to residents

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who did not want to own houses, but rather, preferred to continue renting them.

Innovative construction positively impacted on the community. The positive outcome was evidenced by community improvement with the upgrading process; addressed problems in the previous buildings; fulfilling experience associated with the upgrade; and lack of plans to leave the houses as a result of the upgrade.

Table 2: Outcome of Innovative Construction Employed to Community (a)

Statement	SD (%)	D (%)	N (%)	A (%)	SA (%)	M	SD	p
The community improved with the upgrading process	11.70	9.00	6.3	13.50	59.5	3.46	0.836	0.04
The problems with the previous buildings and community were addressed with the upgrade	10.70	18.9	2.80	37.80	29.80	2.97	0.067	0.02
There are still problems that need to be addressed despite the upgrade	18.4	4.10	7.90	28.90	40.70	3.05	0.789	0.01
The experience with the upgrade is fulfilling	6.0	9.30	5.70	45.90	33.10	3.24	0.941	0.03
I have plans to leave in the future due to the upgrade	26.20	35.10	8.70	18.10	11.9	2.46	0.96	0.01

SD=Strongly Disagree; D=Disagree; N=Neutral; A=Agree; SA=Strongly Agree; M=Mean; SD= Standard Deviation

In addition to the positive outcome on the community, there was increased perception that the community was better than others, increased pride for the community, care for community members, feeling at home, and acceptance as a community member, and community prosperity. On the contrary, innovative construction did not positively impact on some parameters such as the consistent presence of someone to help, and community honesty and trust for one another.

Table 3: Outcome of Innovative Construction Employed to Community (b)

Statement	Increase	Decrease	No Change	Mean	P	SD
This community is better than others	75.70%	0.00%	24.30%	1.26	0.02	0.72
I feel proud of this community	71.70%	22.60%	5.70%	1.41	0.04	0.54
In this community we take care of each other	59.50%	26.00%	14.50%	1.92	0.05	0.21
I feel at home in this community	72.70%	21.10%	6.20%	1.53	0.02	0.58
I feel accepted as a member of this community	75.70%	20.00%	4.30%	1.44	0.03	0.78
This community has prospered in the last five years	94.30%	2.70%	3.00%	1.04	0.00	0.45
If I have a problem, there is always someone to help me	52.10%	28.60%	19.30%	1.95	0.01	0.63
In this community, one has to be alert	14.40%	21.60%	64.00%	2.46	0.01	0.27

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or someone is likely to take advantage of you						
Most people in this community are basically honest and can be trusted	10.80%	27.00%	62.20%	2.62	0.02	0.53

Innovative construction with respect to use of stabilized earth walling blocks, floors and sisal cement roofing sheets positively impacted on the individuals. The positive outcome was evidenced by; willingness to invest further in the houses; individuals' increased willingness to work collectively; and the positive perception on slums and the possibility of better living in slums. There was community improvement with the upgrading process that addressed problems in the previous buildings such as dysfunctional walls, roofs and floors; fulfilling experience and improved self-esteem associated with the upgrade; and lack of plans to leave the houses as a result of upgrade and motivations to own the houses. Innovative construction did not, however, influence individuals' trust for one another.

The positive social impacts of innovative construction included construction of communal facilities including toilets, roads and proper drainage system. Slum residents were guaranteed a secure tenure. Slum upgrading can take many forms, including the regularization of tenure security, provision of adequate infrastructure, development of communal facilities (Majale, 2008). In the Pumwani-Majengo slums upgrading project, beneficiaries also saw better living standards that came in the form of better infrastructure, sanitation, and water supply (Mgele, 2014).

Table 4: Social Impacts of Innovative Construction Materials

Statement	**SD (%)**	**D (%)**	**N (%)**	**A (%)**	**SA (%)**	**M**	**SD**	**P**
Innovative construction was accompanied by the construction of communal facilities	15.5	21.6	9.8	25.8	27.3	3.14	0.71	0.04
There is provision of or improvements to infrastructure with the innovative construction	10.5	15.9	6.4	38.5	28.7	2.22	0.85	0.02
Processes involved in innovative construction ensures that there is security of tenure to slum residents	17.3	19.8	10.7	29.6	22.6	3.16	0.88	0.03
Though the previous houses were replaced, the frameworks of our establishments have not been destroyed	5.0	11.2	5.4	49.5	28.9	2.95	0.64	0.01
Innovative construction led to the displacement of residents hence there is little to no poverty reduction was achieved.	36.2	28.8	11.0	15.8	8.2	3.35	0.79	0.00
Innovative construction developed units are smaller and built with higher densities	34.8	30.8	8.1	17.2	9.1	2.84	0.92	0.01

SD=Strongly Disagree; D=Disagree; N=Neutral; A=Agree; SA=Strongly Agree; M=Mean; SD= Standard Deviation

There were retained frameworks of establishments. Developed units were not significantly smaller and built with higher densities. Similarly, beneficiaries of an upgrade project reported

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satisfaction with the housing quality, size of area, and storage area aspects (Zappettini, 2001). On the contrary, innovative construction was not concomitant to provision of or improvements to infrastructure; and led to the displacement of some residents hence little to no poverty reduction was achieved. These findings were similar to Buckley and Kalarickal (2005) who found out that since slum dwellers were normally displaced during upgrading, little to no poverty reduction is normally achieved.

The positive economic impacts of innovative construction included increased employment opportunities in the maintenance of the upgraded buildings. Similarly, Kvarnstrom (2014) established that slum upgrading normally employed locally produced building materials, such as stabilized soil blocks which were abundant in supply, and required easily acquirable skills hence creating more job opportunities. SSBs used for the upgrading project were locally made and during the construction employment opportunities were created.

Table 5: Economic Impacts of Innovative Construction Materials

Statement	SD (%)	D (%)	N (%)	A (%)	SA (%)	M	SD	P
There is increased employment opportunities in the maintenance of the upgraded buildings	12.7	22.3	11.2	25.5	28.3	2.94	0.51	0.00
There is no minimum and maximum rent fees for the different cadres of people living in the upgraded slums	19.8	9.4	8.9	27.5	34.4	3.13	0.88	0.03
Middle-income individuals do not have opportunity to occupy the upgraded houses meant for the slum dwellers	10.1	15.4	8.1	36.4	30.0	3.24	0.84	0.01
Corruption would affect allocation of units in the upgraded slum dwelling I live in	5.5	8.7	14.3	31.6	39.9	3.85	0.93	0.02
The upgraded dwelling units are affordable	4.7	9.8	10.9	28.7	45.9	3.78	0.82	0.01
The subsidies provided for upgraded slum houses makes them more affordable than other houses of the same standard	2.7	3.2	10.5	35.1	48.6	3.27	0.70	0.02
The houses are of good structural quality and are durable	20.2	9.0	8.8	33.8	28.2	3.32	0.68	0.03

SD=Strongly Disagree; D=Disagree; N=Neutral; A=Agree; SA=Strongly Agree; M=Mean; SD= Standard Deviation

The upgraded dwelling units were more affordable due to subsidies that made them affordable than other houses of the same standard. According to Muraguri (2011), there was high uptake of innovative construction in upgrading slums due to reduced cost, production simplicity, raw materials availability, and social acceptance. On the contrary, Buckley and Kalarickal (2005) argued that providing subsidies for slum upgrading made it very expensive to implement on a big scale, and rent became unaffordable, for the majority of slum dwellers. A study of the Pumwani-Majengo upgrade project found that redevelopment approaches did

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not sufficiently address community economic empowerment aspects to enable slum residents to maintain their livelihoods, as well as a lack of subsidies to relieve high monthly and mortgage payments by beneficiaries (Mgele, 2014).

The upgraded dwelling units were durable and of good structural quality. On the other hand, innovative construction did not bring about minimum and maximum rent fees for different cadre of people living in the upgraded slums. There was lack of opportunity to occupy the upgraded houses by a lot of middle-income individuals. However, allocation process of the units was affected by corruption. These findings echo those of Huchzermeyer (2008) who found out that corruption was a significant negative consequence of slum upgrading that would affect unit allocation. Middle income individuals always had opportunity to occupy the upgraded houses meant for the slum dwellers in Kenya. According to one of the residents, "there are several outsiders who were able to get houses during the slum upgrade, additionally those who were able to pay more were able to influence the process so that they can get bigger and better houses than the rest of the slum dwellers."

4.0 Conclusion

The study was aimed at assessing of the impacts of innovative construction in housing in slum upgrading in Mathare valley. The slum upgrading using innovative technologies had improved the houses for the slum dwellers. Innovative construction positively impacted on the community. There was a fulfilling experience associated with the upgrade and reduced chances of vacating the houses. The upgrading process addressed problems in the previous buildings, however, there were still pending problems that needed to be addressed. The upgrading process positively influenced the social well-being of the community- better perception of slums, unity in working, and increased pride for the community, and acceptance as a community member. The community well-being was associated with its prosperity in the last five years. However, innovative construction did not enhance community honesty and trust for one another.

Innovative construction had positive economic impacts. The upgrading process created employment opportunities. The process led to more affordable upgraded dwelling units that were durable and of good structural quality. Innovative construction did not bring down about minimum and maximum rent fees for different cadre of people living in the upgraded slums; and allocation process of the units was subject to be affected by corruption.

The innovative construction adoption method should not focus on the demolition of the already existing structure but rather improvement of the existing structures. Slums will no longer be viewed as areas for demolition, but rather as areas requiring rehabilitation in a pro-poor approach. Slum upgrading process should involve the residents in assessing and determining their needs to ensure construction of houses that best suit the residents. This is achievable using a bottom up approach which allows for involvement of the residents in the implementation process and aids decision making. The residents can appoint a representative committee to oversee the transition processes. The committee should be motivated and monitored to ensure optimum service delivery. The committee also allows slum residents to be heard by the project sponsors by representing them. This further promotes participation

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of the residents and institutionalization of the innovative construction methods as residents identify with the methods. The process of slum upgrading is often marred with irregularities including corruption, lack of political good-will, and influence from middle income earners in the allocation of houses among others. There is need for effective monitoring of every step in the upgrading process to ensure all stakeholders' satisfaction, avoid displacement and minimize chances of political interference.

5.0 Recommendations

5.1 Presentation of the study, findings, and a portion of the work

A portion of the study was presented at the 16th JKUAT Scientific, Technological, and Industrialization Conference (venue: Council Room, JKUAT & Virtually) on the 24th and 25th of March 2022 under the subtheme: Engineering technologies, ICT, built environment, and infrastructure.

5.2 Conflict of interest

The authors declare that there is no conflict of interest.

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