Housing and Health in Dhaka City's Urban Informal Settlements: Developing the Health Socio-Environmental Housing Index

Final Report of Summative Learning Project (SLP) presented to the
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1. Abstract

Housing has been studied as an important social determinant of health for its influence in an individual's physical and mental well-being. With the growing population in Dhaka city, many families are being forced to live in urban informal settlements in search of cheap and available housing. Characterized by inadequate basic services, informal settlements are a public health issue of concern as it increases the likelihood of individuals experiencing adverse health outcomes.

A cross-sectional study was conducted across Dakshinkhan and Shyampur Informal settlements. With a systematic sampling approach 316 households were surveyed which resulted in health status information for 1219 individuals. Household information was collected for 16 dimensions of housing quality, and individual health information was collected for respiratory conditions, infectious diseases, and mental health disorders (only for female respondents above the age of 18, n=316). A composite index was created using principal component analysis and scores were normalized (0= inadequate housing, 1= adequate housing) to assess housing quality through the Healthy Socio-Environmental Housing Index (HSEH). Multiple logistic regressions were used to assess the association between the HSEH index and health.

Findings suggest a significant association between housing and health status, with improving housing quality associated with better health outcomes. Multiple logistic regression resulted in significant relationship for (i)respiratory conditions (OR:0.16, CI: 0.07-0.37), (ii)infectious diseases (OR:0.18, CI: 0.05-0.55) and (iii)mental health disorders (OR: 0.28. CI: 0.07-1.10) with housing quality.

Inadequacies in housing quality increase the likelihood for negative health outcomes, highlighting the importance of housing as a public health concern. For Dhaka city to equitably serve its residents, it needs to take immediate action to improve the standard of housing across the city through policy and interventions. The HSEH is useful in these policy discussions as an appropriate means of monitoring and evaluation, especially to recognize areas of priority by degree of inadequate quality across different informal settlements in the city.

2. Introduction

2.1 Background

Rapid development across nations has pushed 55% of the total global population to settle in urban areas with an expected increase in this proportion to come by 2050. Estimates by the UN project an additional 2.5 billion individuals, 90% of which is expected to be within the emerging economies in Asia and Africa (United Nations Department of Economic and Social Affairs, 2019). Rapid urban migration pushes individuals to seek out cheap and available housing in densely populated cities, giving rise to informal settlements to meet the deficit created in housing quantity (Nassar & Elsayed, 2018). Across the world at least one billion people live in informal settlements which lack basic services of housing such as water, sanitation, security of tenure and durability of structure alongside overcrowded conditions (Habitat, 2015; United Nations Human Settlements Programme, 2020). However, an increase is expected as projections estimate a rise to 3 billion by 2030 due to global pressures across countries (UNStats, 2018). South Asia is a major regional contributor to this global phenomenon, with India accounting for an additional 416 million urban dwellers between 2018 and 2050 (United Nations Department of Economic and Social Affairs, 2019). Some of the most densely populated metropolitan cities globally are located in South Asia, becoming home to a large proliferation of informal settlements. In South Asia, about 130 million of its urban residents lived in inadequate housing conditions, and an additional 203 million units of housing will be required to meet the demand for adequate housing in the region's urban settlements by 2050 (Ellis & Roberts, 2016).

Bangladesh is currently experiencing one of the fastest rates of urbanization in the world as a result of its successful economic development. Employing a centralized approach to development, Dhaka city has been forced into a pattern of unsustainable urbanization which has resulted in an unmet needs for its residents. Moreover, disasters throughout the country have been pushing for an increase in urban migration, increasing the burden of residents in urban areas making it difficult for the government to meet the demand for housing in both quantity and quality (Bah et al., 2018). The demand for housing has pushed the market to build cheap housing in informal settlements, with 52% of the nation's urban population residing in informal settlements with inadequate housing conditions (World Bank, 2020).

As an established social determinant of health, housing has been studied as an important component of health equity (Rolfe et al., 2020). Previous attempts at understanding housing have been through the lens of housing inadequacy, looking qualitatively at housing satisfaction for physical and environmental conditions (Biswas et al., 2021). However standardized measures of inadequacies are still lacking, which has led the World Bank to establish the Adequate Housing Index (AHI) as a global standard to recognize gaps and dissatisfaction in housing availability and policies across nations. By focusing on quantitative measurements and utilizing data from the Multi-Purpose Household Surveys across 64 emerging economies, the AHI recognizes 7 key dimensions of housing which are reflected in the UN Agenda 2030 for Sustainable Development. The AHI recognizes 7 areas of adequacies, name (1) sufficient access to water, (2) sufficient water, sanitation and hygiene (WASH) facilities, (3) sufficient living space (4) durability of structure, (5) security of tenure, (6) sufficient access to electricity, and (7) access to clean cooking sources (Behr et al., 2021). Although these dimensions provide a good measure for comparing housing inadequacies across nations, the index lacks an investigation into some key housing characteristics which affect the health of individuals. Numerous studies have been conducted looking at specific housing characteristics as a result of unplanned urbanization and their impact on respiratory conditions, infectious disease incidence, and mental health disorders (Rahaman et al., 2023).

Houses which have poor indoor air quality due to solid fuel combustion, have been linked with respiratory illnesses such as asthma and chronic obstructive pulmonary disease (Nahar et al., 2016). Solid fuel combustion can be caused by the use of traditional wood stoves or brick ovens as well as a lack of proper ventilation in households can lead to a deterioration of indoor air quality (*WHO Indoor Air Quality Guidelines*, 2014). Without proper ventilation, contaminants released during cooking or other household activities can remain in the household and cause harm through long-term exposure (Sun & Wallace, 2021). Lack of adequate clean water, sanitation infrastructure and consequently practices in housing areas contribute to the spread of infectious diseases, such as cholera and diarrhea. While drinking water definitely plays a role in the spread of these diseases, inability to access clean water for other uses such as hygiene maintenance or cleaning can also impact an individual's susceptibility to them (Hossain &

Huggins, 2021). Waterlogging has also been linked to the spread of infectious diseases, with an increased incidence of diarrhea, dysentery, malaria/dengue, and skin infections due to vector breeding and cross-contaminations (Hossain et al., 2022). While 35% of Dhaka city is characterized as high/very highly vulnerable to waterlogging, a large number of poorly structured households in informal settlements were found to be within these zones through GIS spatial mapping suggesting increased susceptibility to structural damages or increased spread of disease in these households (Alam et al., 2023).

Catastrophic household rent is defined as the stressor added on the household members when an excessive amount of their cumulative income is spent on rent, limiting their economic flexibility for other concerns. A rent to income ratio of 30% can be exceeded and present an unaffordable burden on household incomes, with many not being able to afford housing financing (Giti, 2018; Jahan & Abul Kalam, 2012). Increasingly heavy financial burdens associated with housing leaves a smaller fraction of disposable income to be spent on medicinal costs, education, or other recreational activities (UN Habitat, 2019). This additional stress of affordability caused by housing can be linked to mental health disorders amongst household heads or breadwinners in families. Moreover, living in overcrowded and unsafe environments has been studied to lead to reportedly higher levels of anxiety and depression, arising from lack of tenure, neighborhood insecurity and sometimes ostracization from communities in urban informal settlements (Hijol et al., 2024)

2.2 Gaps in the Literature

The dimensions of housing structure and other characteristics which impact health are not adequately captured in the AHI. Given that the AHI needed to be standardized for 64 different emerging economies, it leaves out many housing characteristics which affect health status within specific countries. While other indices have been suggested in High-Income Countries (HIC) such as the Housing and Environmental Quality Index, as well as the Healthy Housing Index which look at housing quality through the lens of structural deprivations and resident behaviors, studies lack in the Low-Middle Income context(Chu et al., 2022; Keall et al., 2007). Beyond the study conducted by the World Bank to establish the AHI, attempts have not been made in the urban informal settlement context to study the impact of housing and health through a composite

index. Studies have recognized other housing characteristics, specific to Bangladesh, which impact health such as: sharing of WASH facilities, sufficient time of access for electricity, exposure to waterlogging, damp walls, leaking roof, poor protection against extreme temperatures, and ventilation status in rooms. However, these measures have been omitted from the AHI in favor of standardization across many countries which leaves a cap in contextual comprehensiveness for Bangladesh's needs. Moreover, as respiratory conditions, and infectious diseases remain a significant concern across the nation, with mental health disorders also rising in prevalence, studying housing can allow us to explore the impact of this social determinant of health in our context.

2.3 Justification

Housing remains one of the most pertinent inadequacies in Dhaka city, and with the increase in demand for cheap housing, informal settlements are growing in number. Studying health status associated with living in informal settlements can highlight the severity of public health burden caused by incomprehensive housing policies. By developing an index that captures the relationship between housing and health, it can provide a measure for policymakers, researchers and community members to recognize how to improve health outcomes through a household-based approach. This approach is particularly useful for contexts like informal settlements where health and housing conditions are below national averages. While Bangladesh continues to answer its public health concerns through a clinical approach, ignoring the substantial effect that an individual's housing quality can have on them will result in redundant treatments, as the root cause is not being answered. An index which considers context-specific factors will provide a holistic understanding of housing as a determinant of health, and can highlight areas of necessary interventions for the local governments to implement. Furthermore, the housing index can be used to monitor the improvements made in housing quality by quantifying multiple variables as a composite. This allows ease in monitoring and evaluation of different interventions made by researchers and the government. Given the nuanced impact of housing on the individual, interdisciplinary approaches are necessary to improve public health outcomes through housing policies. This requires an easy to understand, and measurable index which can be involved in real-world policy making.

2.4 Research Questions

RQ1: What is the prevalence of respiratory conditions, infectious diseases and mental health disorders for households in urban informal settlements in Dhaka city?

RQ2: What is the relationship between housing conditions as measured by the Healthy Socio-Environmental Housing (HSEH) Index and health outcomes (respiratory conditions, infectious diseases and mental health disorders) amongst residents of selected informal settlements?

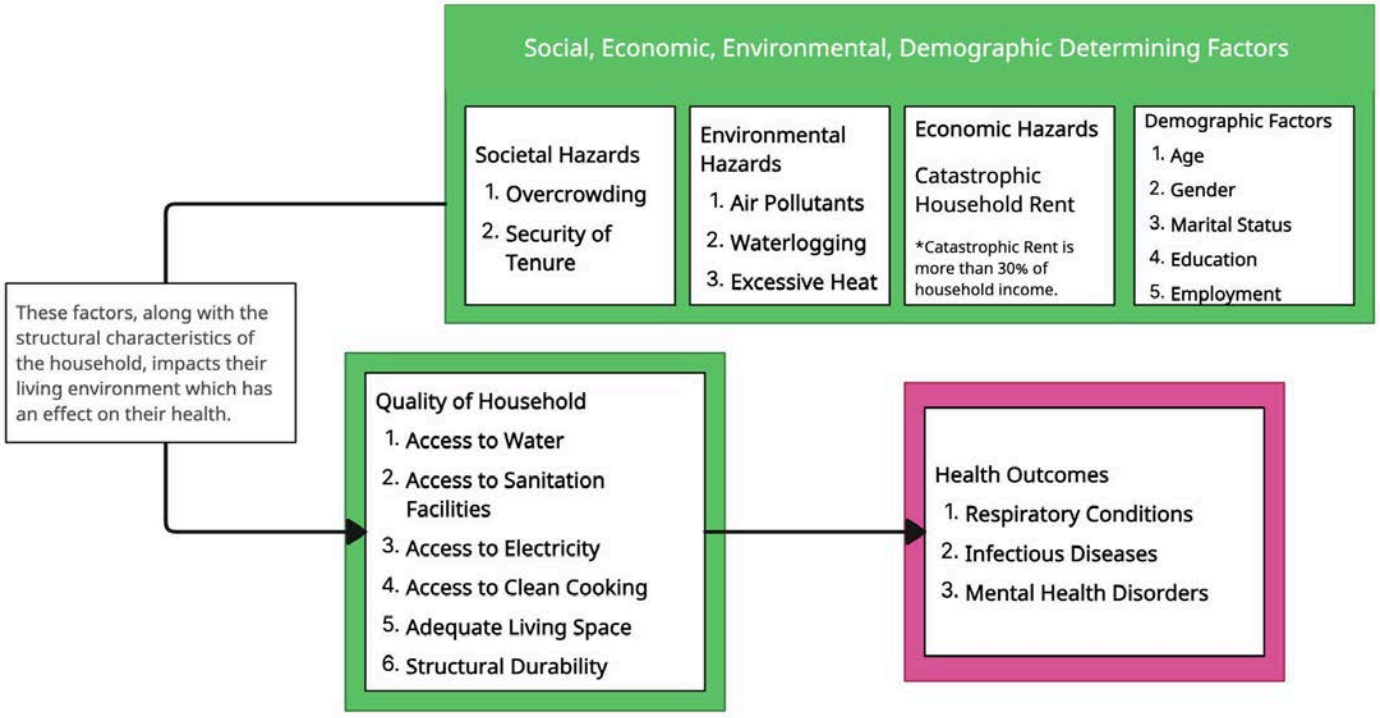
2.5 Research Objectives

Primary: Assess the relationship between housing conditions and health outcomes for residents in urban settlements for Dhaka city through the use of the HSEH index.

Secondary: (i)Generate a housing index (HSES) which incorporates evidence-based indicators to further develop previously existing indices. (ii) Investigate the one-month prevalence of respiratory conditions, infectious diseases and mental health disorders.

3. Conceptual Framework

The conceptual framework was created after consulting the World Bank AHI document (Behr et al., 2021), as well as other relevant works of literature mentioned in the background which look at specific housing conditions and its effect on health.



4. Methodology

4.1 Study Design and Setting

The study is designed as a cross-sectional study conducted between November 26th to December 7th, 2024 across two urban informal settlements in Dhaka city. The study sites were purposively selected as Dakshinkhan and Shyampur informal settlements.

4.2 Sampling Strategy

To measure health status the study looked at the prevalence of respiratory conditions and infectious diseases across all age groups. A combined estimate for infectious diseases was not found, although major conditions such as cholera and tuberculosis remain of significant public health concern. One study estimates skin infection prevalence in the Turag-Tongi Riparian areas as 12.7%, while dysentery and diarrhea are estimated at 12.5% (Prodhan & Nasreen, 2023). National estimates of respiratory conditions in urban settlements remain unexplored, although ARI estimates for children under 5 is estimated at 1.45 in the Bangladesh Demographic Health Survey(The DHS Program, 2023). However, these estimates were not applicable to the study population, due to a difference in location and age group.

The required sample size was calculated using the Cochran's sample size estimation formula, and presuming a prevalence of 50% to ensure the largest sample size possible with a margin of error of 10%. Alongside this, due to the complicated design of the study, a design effect of 1.5 was assumed.With a 10% non-response rate each site resulted in 158 households for a total sample of 316 households combined

$$n_0 = \frac{z^2 \cdot p \cdot (1-p)}{e^2} = \frac{1.96^2 \cdot 0.5 \cdot 0.5}{0.1^2} = 96 \times 1.5 \approx 144$$

$$144 \times 1.10 = 158.4 \approx 158 \times 2 = 316$$

Given the research interest the sample was calculated on a household level in the selected informal settlements, and respondents were women identified as either the household head, or the spouse of the household head. In order to meet the objective of the study the unit of analysis was fixed as individuals, with demographic and health information collected for every residing member of the household.

Figure 1: Household Distribution Map for Shyampur

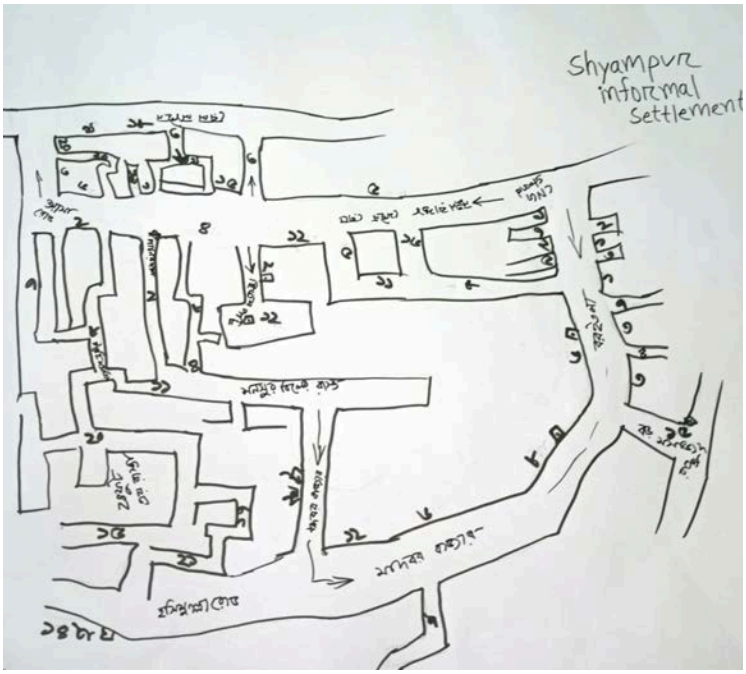


Figure 2: Household Distribution Map for Dakshinkhan

In order to employ a systematic random sampling approach, a household distribution map needed to be created for both sites. To achieve this, social mapping was utilized to determine the total number of households and the geographic distribution of each area with the involvement of local community members. A fixed interval was to be decided for each location depending on the total number of households in the area. The research team prepared maps for both Shyampur and Dakshinkhan with locations of households, and the density of households in the mapped roads. Only households which fall under the UN Habitat definition of informal settlements were mapped. The resulting maps located 1500 households in Shyampur, while 450 households were found in Dakshinkhan which led to a household interval of 10 households and 3 households respectively.

4.3 Inclusion and Exclusion Criteria

Households included in the study were those who had a female respondent above the age of 18 available to provide consent and participate in a survey for 45-60 minutes. Families who have lived in the designated area for less than 1 year or which did not have any present members during survey time were excluded from the study.

4.4 Tool Development

The data collection tool for this study was structured questionnaires deployed through kobotoolbox. The questions for household characteristics were adapted from the Household Income and Expenditure Survey (HIES) 2022 to ensure the questions were comprehensible and comfortable to answer for respondents. The questionnaire included 3 sections: (i) household characteristics; (ii) household member health status and (iii) respondent mental health status. For the first research question, health-related questions were adopted from the HIES 2022 for health status assessment for each household member with further appended options available from Multiple Indicator Cluster Survey (MICS) 2019. For the mental health status of the respondent, the Beck Depression Inventory II (BDI-II) and Beck Anxiety Inventory (BAI) were used to screen for the respective disorders. For the second research question, the household characteristics were specifically taken from HIES 2022, and included questions on income, household structural durability, WASH access, and cooking fuel. The questionnaire was prepared in English, and validated translation of adopted questions from HIES, MICS and BAI tools were used (Bangladesh Bureau of Statistics (BBS) & UNICEF Bangladesh, 2019; Naher et al., 2022; *Preliminary Report*, 2023). The BDI tool did not have any accessible bangla translation, and was translated by our team and validated through pretesting.

4.5 Data quality control and collection procedure

A one-day training was provided to each field data collector which ensured familiarity with the objectives of the study and the questionnaire. The questionnaire was pretested to identify any ambiguities or inconsistencies in question structure which may lead to confusion for the respondent. Pretesting of the questionnaire was conducted in Karail slum in order to validate both questionnaire structure and content, with a total of 14 households (4.4% of the total sample size) sampled. Supervision plans were established to ensure the completeness and consistency of data, with corrections made after follow up if necessary. Each field data collector was assigned a designated section of the area which ensured that there were no overlaps in data collection. The field data collector is to collect information about each individual's health status, and information about the household from the respondent. Due to the design of the study, questions pertaining to extreme indoor temperature and waterlogging were asked specifically for seasons such as water logging during monsoon and extremely hot rooms during the summer.

4.5 Variables of Interest

For our data analysis our variables of interest can be divided into 2 categories: Housing characteristics and individual disease status. Further details can be found in the Annex table 1.

Table 1a: Variables used for housing characteristics

SL	Independent Variable	Definition (to be considered adequate housing quality)
1	Durable Housing**	Durable materials used for Floor, Walls, and Roof. With no leaking roof
2	Occupancy Status*	Rented or Owned Household
3	Overcrowding*	less than 3 people living per room
4	Sanitation Access**	Toilet facility is located within the household, not shared by any other household and of improved type.
5	Drinking Water Access**	Drinking water is from an improved source, and access is available for more than 22 hours a day.
6	Fear of Eviction*	Household members do not experience fear of eviction by landlord or government
7	Access to Electricity**	Access to electricity is available for at least 22 hours a day, with sufficient power for basic services.
8	Good Indoor Air Quality**	Clean cooking fuel utilized in a ventilated kitchen
9	Other Water Access	Water for other uses comes from a piped source with access available for more than 22 hours a day.
10	Affordability	Rent or Loan Repayment is less than 30% of total monthly income.
11	Light Needed during Daytime	Rooms are sufficiently illuminated by natural light during the day
12	Waterlogging	No waterlogging experienced inside the household, or in its immediate vicinity after rainfall
13	Damp Walls	Walls do not remain damp to touch after rainfall
14	Waste Disposal	Formal waste collection is practiced with no noticeable smell entering the household
15	Extreme Indoor Temperature	Room does not get extremely hot during the summer, or extremely cold during the winter
16	Ventilation	Every room in the household has a window

*Adopted from AHI ** Adopted from AHI with modifications (see Annex Table 1)

Table 1b: Variables used for disease status

SL	Dependent Variable	Definition
1	Respiratory Conditions	Self-reported cases of asthma, bronchitis, pneumonia, tuberculosis, chronic coughing, difficulty breathing.
2	Infectious Diseases	Self-reported incidents of diarrhea/dysentery, skin infections, cholera, jaundice, typhoid, scabies within the last month.
3	Mental Health Disorders	Depression and Anxiety measured using Beck Anxiety Inventory (BAI) and Beck Depression Inventory-II (BDI-II).

4.6 Data Analysis Plan

The data was collected using Kobotoolbox and exported to STATA version 17.0 for analysis. Exploratory data analysis was performed in two phases. For the descriptive analysis the frequency distribution was calculated for each housing condition, alongside confounding variables of interest for each individual i.e. age, religion, literacy status, education, employment status, and marital status. Secondly, bivariate analysis was conducted to recognize potential variations in each housing characteristics for presence of respiratory conditions, infectious diseases, or mental health disorders. To create a composite index of housing characteristics, all housing related variables were utilized to run Principal Component Analysis (PCA). As a dimensionality reduction technique, it identifies patterns in data to capture useful information while minimizing redundancy. The output for PCA is an index which captures different aspects of housing conditions, resulting in the Healthy Socio-Environmental Housing Index (HSEH). Multivariable logistics regression was used to find associations between the HSEH index score (independent variable) and respiratory conditions, infectious diseases and mental health disorders (dependent variable) across three levels of significance: less than 0.01, less than 0.05, and less than 0.1. Several socio-demographic variables were used as confounding variables to adjust the background imbalance.

4.7 Ethical Considerations

BRAC James P. Grant School of Public Health provided ethical approval for the study through IRB approval (MPH-2024-010). Before data collection was attempted, a signed letter for permission to conduct our study was collected from municipalities for Dakshinkhan and Shyampur. Due to the uncertain political atmosphere of Bangladesh at the moment, it was necessary to ensure that the local community leaders were aware and willing to cooperate with the survey. Written informed consent was taken before the start of the survey from the respondents, and thorough confirmation was obtained for their personal safety and avoiding any disruptions to their life. For individuals who were unable to provide written consent due to social or physical barriers, their households were skipped.

5. Findings

5.1 Background Characteristics of Individuals from Sampled Households

A total of 316 households were surveyed from both Shyampur and Dakshinkhan, which resulted in a total of 1219 individuals which is the unit of analysis. Among the individuals interviewed, most of the participants were aged 18-48 (54%) while only 10.8% of the total respondents were children under 5. Although only 32.8% of the participants lacked any formal education, many reported an inability to read or write which resulted in the rate of illiteracy amongst participants to be 36.75%. Most of the participants aged over 18 are married (81.13%) and almost 36% of them are unemployed.

Table 2a: Background Characteristics of the Individuals of the Sampled Households

Individual Characteristics	**N**	**%**
Age (N=1219)		
Under 5 Years Old	132	10.80
5-18 Years Old	308	25.30
18-49 Years Old	665	54.60
50 Above	114	9.40
Religion (N=1219)		
Muslim	1,188	97.50
Non-Muslim	31	2.50
Education (N=1219)		
No Formal Education	400	32.80
Primary	388	31.80
Secondary	372	30.50
Higher Secondary and above	28	2.30
Others	31	2.50
Literacy Status (N=1219)		
Illiterate	448	36. 75
Literate	771	63.25
Employment Status (N=779) [For Individuals aged 18+]		
Unemployed	279	35.80
Employed	500	64.20
Marital Status (N=779) [For Individuals aged 18+]		
Currently Married	632	81.13
Unmarried	147	18.87

5.2 Household Characteristics of Sampled Households

As seen in Table 2b out of the 316 households surveyed, most of the households (56.3%) had a monthly income more than 20,000, however, only 18.4% of families lived in affordable housing. Majority of the households lived in overcrowded conditions, with 71.8% of families lacking sufficient living space. Only 25% of the sampled households had issues with structural

durability, as most were built with finished materials. Sanitation access and drinking water access remains a concern as 79.7% and 87.7% of the households respectively lack improved access. More than half of the households (50.6%) had unsafe waste disposal practices, while 62% had bad indoor air quality. Other common characteristics of concern which were found were extreme indoor temperature (69.9%), and waterlogging (59.81%).

Table 2b: Housing Characteristics of the Sampled Households in Shyampur and Dakshinkhan

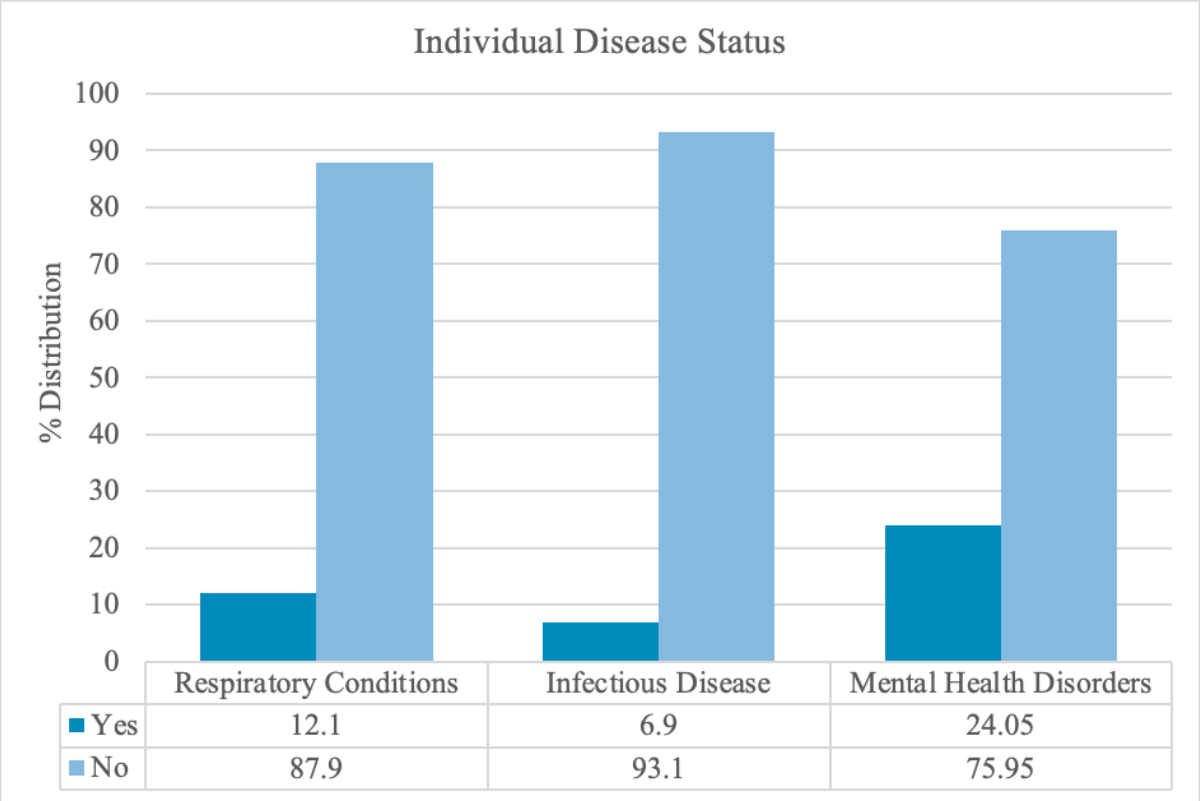
Household Characteristics (N=316)	N	%
Area		
Shyampur	158	50.00
Dakshinkhan	158	50.00
Household Income		
Less than 20,000	178	56.33
More than 20,000	128	43.67
Affordable Housing		
Unaffordable Housing	58	18.40
Affordable Housing	258	81.60
Overcrowding in Household		
Overcrowded	227	71.80
Sufficient Living Space	89	28.20
Fear of Eviction		
Yes	26	8.20
No	290	91.80
Durable Housing		
Not Durable	79	25.00
Durable	237	75.00
Sanitation Access		
Unimproved Sanitation Access	252	79.70
Improved Sanitation Access	64	20.30
Source of Drinking Water		
Unimproved Water Access	277	87.70
Improved Water Access	39	12.30
Source of Water for Other Uses		
Unimproved Water Access	72	22.80
Improved Water Access	244	77.20
Waste Disposal		
Unsafe Waste Disposal	160	50.60
Safe Waste Disposal	156	49.40
Indoor Air Quality		
Bad Indoor Air Quality	196	62.00
Good Indoor Air Quality	120	38.00
Extreme Indoor Temperature		
Yes	221	69.90
No	95	30.10
Damp Walls		
Yes	81	25.60
No	235	74.40

Lack of Natural Light during the Day		
Yes	133	42.10
No	183	57.90
Ventilated Rooms		
Unventilated	63	19.90
Ventilated	253	80.10
Waterlogging		
Waterlogging Present	189	59.81
No Waterlogging	127	40.19
Occupancy Type		
Rented	294	93.00
Owned	22	7.00
Access to Electricity		
No	93	29.40
Yes	223	70.60

5.3 Disease Status within Sample

While respiratory conditions and infectious diseases were studied for all members in a household with a total of 1219 individuals, with respective one-month prevalence rates of 12.1% and 6.9%. For mental health disorders, amongst the smaller sample of 316 women aged above 18, there was a prevalence of almost 25% severe mental health disorders found.

Figure 3: Individual Disease Status



5.4 Association between Sample characteristics with Disease status

The relationship between housing characteristics and health was explored using the one-month prevalence of respiratory conditions, infectious diseases and mental health disorders in Table 3. Most notably, unimproved access to sanitation was found commonly amongst those who had some type of respiratory condition (83.7%), infectious disease (70.2%) and mental health disorder (82.9%). While, income varied amongst households but results in the first column show that the majority (62.6%) of those who had respiratory conditions had a household income less than 20,000 BDT. Respiratory conditions were also found more commonly amongst those who lived in households with unsafe waste disposal practices and bad indoor air quality, with 59.2% of households 50.3% of households respectively. Respondents with respiratory conditions also reported unimproved access to drinking water, with 87.8% of those affected coming from such households.

The second column shows that out of those who had infectious diseases, 79.8% reported being from households who had unimproved access to drinking water, while only 38.1% reported unimproved access to water for other uses. Moreover, 82.1% of respondents who have some type of infectious disease experience extreme indoor temperatures within their dwellings. Majority of those who suffer from infectious diseases also report waterlogging and lack of natural light as concerns with 63.1% and 52.4% affected respectively.

For mental health disorders, in the third column of Table 3, the majority of respondents (65.7%) are found to be residents of Shyampur. For the women sampled, 82.9% of those who had mental health disorders had unimproved access to sanitation. This is mirrored with access to drinking water, as 88.2% of those who had mental health disorders also had improved access to drinking water. Other common factors associated with mental health disorders include extreme indoor temperature, unsafe waste disposal, waterlogging and bad indoor air quality.

Table 3: Association between Individual and Household Characteristics with Disease Status for Household Members in Shyampur and Dakshinkhan Informal Settlements

	Respiratory Conditions		**Infectious Diseases**		**Mental Health Disorders**	
	Yes (n=147)	**χ2**	**Yes** (n=84)	**χ2**	**Yes** (n=76)	**χ2**
Age						
Under 5 Years	26 (17.7%)	11.42***	12 (14.3%)	2.88	N/A	0.64
5-18 Years Old	26 (17.7%)		(27.4%)			
18-49 Years Old	83 (56.5%)		(46.4%)		(88.2%)	
50 Above	12 (8.2%)		(11.9%)		(11.8%)	
Gender						
Female	88 (59.9%)	8.67***	(48.8%)	0.00	N/A	
Male	59 (40.1%)		(51.2%)			
Marital Status						
Married	80 (54.4%)	0.44	(56.0%)	0.61	(90.8%)	0.00
Unmarried	67 (45.6%)		(44.0%)		(9.2%)	
Employment Status						
Unemployed	95 (64.6%)	6.95***	(59.5%)	0.93	(56.6%)	0.85
Employed	52 (35.4%)		(40.5%)		(43.4%)	
Literacy Status						
Illiterate	54 (36.7%)	0.29	(36.9%)	0.00	(39.5%)	3.35*
Literate	93 (63.3%)		(63.1%)		(60.5%)	
Area						
Shyampur	78 (53.1%)	1.35	47 (56.0%)	1.97	50 (65.7%)	9.97***
Dakhshinkhan	69 (46.9%)		37 (44.0%)		26 (34.3%)	
Income						
<20,000	92 (62.6%)	10.79***	39 (46.4%)	0.42	48 (63.2%)	1.89
>20,000	55 (37.4%)		45 (53.6%)		28 (36.8%)	
Affordable Housing						
Unaffordable	25 (17.0%)	0.03	20 (23.8%)	2.43	16 (21.0%)	0.49
Affordable	122 (83.0%)		64 (76.2%)		60 (79.0%)	
Overcrowding in Household						
Overcrowded	115 (78.2%)	0.00	61 (72.6%)	1.63	51 (67.1%)	1.11
Sufficient Space	32 (21.8%)		23 (27.4%)		25 (32.9%)	
Fear of Eviction						
Yes	16 (10.9%)	1.83	14 (16.7%)	9.08**	11 (14.5%)	5.16**
No	131 (89.1%)		70 (83.3%)		65 (85.5%)	
Durable Housing						
Not Durable	54 (36.7%)	10.71***	27 (32.1%)	1.97	27 (35.5%)	5.91**
Durable	93 (63.3%)		57 (67.9%)		49 (64.5%)	
Sanitation Access						
Unimproved	123 (83.7%)	3.99*	59 (70.2%)	2.47	63 (82.9%)	0.74
Improved	23 (16.3%)		25 (29.8%)		13 (17.1%)	
Drinking Water Access						
Unimproved	129 (87.8%)	0.00	67 (79.8%)	5.40**	67 (88.2%)	0.02
Improved	18 (12.2%)		17 (20.2%)		9 (11.8%)	
Water for Other Uses Access						
Unimproved	54 (36.7%)	20.05***	32 (38.1%)	12.96***	12 (15.8%)	2.78*
Improved	93 (63.3%)		52 (61.9%)		64 (84.2%)	

Waste Disposal						
Unsafe Disposal	87 (59.2%)	3.21*	47 (56.0%)	0.49	41 (53.9%)	0.44
Safe Disposal	60 (40.8%)		37 (44.0%)		35 (46.1%)	
Indoor Air Quality						
Bad Air Quality	74 (50.3%)	9.39***	51 (60.7%)	0.04	36 (47.4%)	9.13***
Good Air Quality	73 (49.7%)		33 (39.3%)		40 (52.6%)	
Extreme Indoor Temperature						
Yes	104 (70.7%)	0.12	69 (82.1%)	6.82***	57 (75.0%)	1.22
No	43 (29.3%)		15 (17.9%)		19 (25.0%)	
Damp Walls						
Yes	51 (34.7%)	7.56***	33 (39.3%)	9.13***	21 (27.6%)	0.21
No	96 (65.3%)		51 (60.7%)		55 (72.4%)	
Lack of Natural Light during the Day						
Yes	54 (36.7%)	3.23*	44 (52.4%)	2.75*	33 (43.4%)	0.07
No	93 (63.3%)		40 (47.6%)		43 (56.6%)	
Ventilated Rooms						
Unventilated	38 (25.9%)	3.23*	14 (16.7%)	0.72	21 (27.6%)	3.71*
Ventilated	109 (74.1%)		70 (83.3%)		55 (72.4%)	
Waterlogging						
Waterlogged	95 (64.6%)	0.20	53 (63.1%)	0.41	36 (47.4%)	6.44**
No Waterlogging	52 (35.4%)		31 (36.9%)		40 (52.6%)	
Occupancy						
Rented	95 (92.5%)	0.34	53 (92.9%)	0.30	36 (94.7%)	0.45
Owned	52 (7.5%)		31 (7.1%)		40 (5.3%)	
p-value: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$						

5.5 PCA Calculation for Health Socio-Environmental Housing Index (HSEH)

HSEH index is constructed incorporating sixteen variables related to housing conditions using *pca* command in STATA. Principal components corresponding to an eigenvalue greater than 1 were selected to capture maximum of the variation. A total of 7 components has been selected with the lowest eigenvalue equal to 1.00164. These seven components together explained almost 65% of the total variation. This ensures that sufficient information is being retained from the original variables while simplifying the model for easy interpretation. To scale this index into an interpretable range, the score was normalized. To normalize the score, the mean of the sample, and its standard deviation were calculated. The mean score was subtracted from the raw score, and divided by the standard deviation of the sample for the normalized score. The normalized scores are shown in the distribution of samples in figure 4. The figure showcases the slightly positive skew for the distribution, and the range of scores of between zero and 1. The mean value of the index for this sample is around 0.58 which suggests that most households experience some form of inadequacy in their housing dimensions as noted in Table 4.

Figure 4: Percent Distribution of HSEH Index Scores in Sample

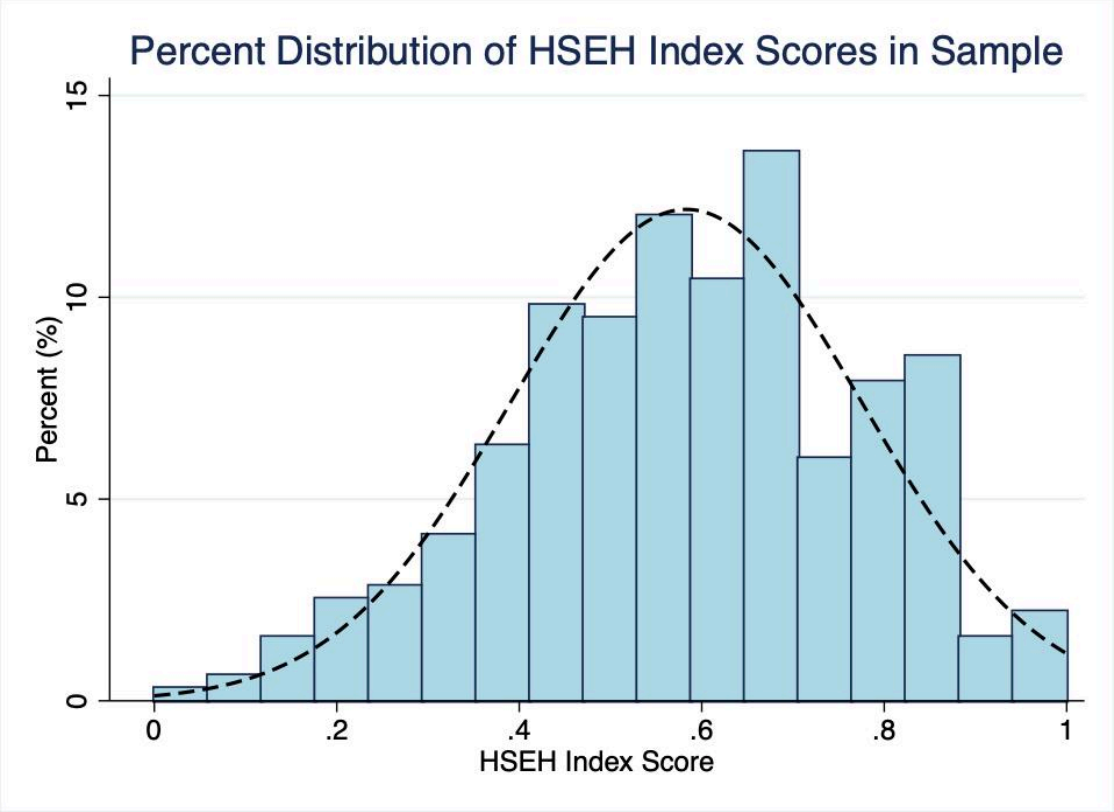


Table 4: HSEH Index Score by Area

HSEH Score	Mean Score	Minimum Score	Maximum Score
Sample	0.58	0.00	1
Only Shyampur	0.57	0.06	0.96
Only Dakshinkhan	0.59	0.00	1

5.6 Association between HSEH Index Score and Health Outcomes

Table 4 shows the results of multiple logistic regression of the effect of HSEH and other confounders on different disease conditions. Results show with improved housing conditions the odds of those diseases decrease significantly.

Table 4: Adjusted logistic regression results Respiratory Conditions, Infectious Diseases, and Mental Health Disorders for Household Members in Shyampur and Dakshinkhan Informal Settlements

	Respiratory Conditions (N=1219)			**Infectious Diseases (N=1219)**			**Mental Health Disorders (N=316)**		
	AOR	**95% CI**		**AOR**	**95% CI**		**AOR**	**95% CI**	
		Lower	Upper		Lower	Upper		Lower	Upper
HSEH Index	0.16***	0.07	0.39	0.18***	0.05	0.55	0.28*	0.07	1.10
Literacy Status									
Illiterate	*reference*								
Literate	1.2	0.80	2.06	1.29	0.72	2.32	0.62	0.34	1.12
Employed									
No	*reference*								
Yes	0.68*	0.43	1.05	0.87	0.48	1.56	1.27	0.74	2.17
Age									
Under 5	*reference*								
5-18	0.32***	0.16	0.65	0.69	0.29	1.65		N/A	
18-49	0.49	0.21	1.15	0.10***	0.02	0.54	*reference*		
50+	0.46*	0.19	1.13	0.21*	0.04	1.09	1.07	0.43	2.68
Marital Status									
Married	*reference*								
Unmarried	0.83	0.46	1.51	0.16**	0.04	0.66	0.76	0.29	1.97
Gender									
Female	*reference*								
Male	0.65**	0.44	0.96	0.97	0.59	1.59	N/A		
p-value: *** p < 0.01, ** p < 0.05, * p < 0.1									

The odds of developing respiratory issues decreases with an increase in HSEH score. The model showed that for every 1 unit increase in HSEH score for the household, the odds of developing respiratory illness decreases by 84% (OR:0.16, CI: 0.07-0.37). Only a prevalence of 6.9% was found for infectious diseases for both Shyampur and Dakshinkhan combined. The odds of having an infectious disease decreases with an increase in HSEH score. For every 1 unit increase in HSEH score, a decrease of 82% odds of developing infectious disease is seen (OR:0.18, CI: 0.05-0.55). Using the BDI-II and BAI tools to recognize prevalence of mental health disorders resulted in a significantly high prevalence of mental health disorders at 24.05% for both areas combined. The model showcased a decreasing odds of developing mental health disorders with an increase in HSEH score. This statistically significant finding suggests that for every one unit increase in HSEH score a decrease of 72% odds can be seen for developing mental health disorders (OR: 0.28. CI: 0.07-1.10).

6. Discussion

The inadequacies in housing presented in the form of structural quality, societal, environmental or economic hazards can lead to differentially distributed opportunities for health and well-being of individuals (Rahaman et al., 2023). Although indices exist globally to look at measures of housing quality, studies are lacking in the context of Bangladesh making it difficult to approximate how housing can affect individuals health. This paper outlined a standardized and reproducible approach to developing a housing quality index, incorporating various domains of housing characteristics which can lead to deprivation of health as outlined in research. Unlike other measures which have tried to quantify housing inadequacy through perception of residents through housing satisfaction, or foregone context specific variables in the pursuit of creating an internationally standardized composite value, the HSEH works to present an empirical summary of housing inadequacy in the informal settlement context of Bangladesh (Biswas et al., 2021). Beyond contextualized evidence on housing inadequacy, the index was further able to distinguish the relationship between housing quality and adverse health outcomes (respiratory conditions, infectious diseases, and mental health disorders).

The existence of these concerns across informal settlements make it difficult to capture the nuances of housing through the 7 dimensions of Adequate Housing Index. By incorporating these additional dimensions into our HSEH index (waste management, access to natural light, indoor ventilation, damp walls, waterlogging, extreme indoor temperature, affordability, occupancy type, water access for other uses) and modifying previous dimensions for more robust measures (overcrowding for sanitation facilities, kitchen location and ventilation for cooking fuel type and leaks for structural integrity) we are able to establish a framework that better captures the association between health and housing for the informal settlements context in Bangladesh. Our study found associations between housing and health outcomes for respiratory conditions, infectious diseases and mental health disorders, suggesting that with an increase in inadequacy, the household members were at higher odds to experience adverse health outcomes.

The indicators of housing quality are strongly associated in the study area given their inherent nature of being intertwined with one another. While individual metrics have been effective for identifying housing quality, their highly correlated nature suggests that using an index with

multiple indicators of housing quality such as those created in the USA for the Poor Quality Index (PQI) (American Housing Survey, 2013). By including numerous variables, the HSEH index is developed to capture more robust data in comparison to single indicators. Single indicators can be subjected to societal or geographical trends which can cause difficulties when comparing over place and time. The composite index allows us to make inferences about health status for residents for informal settlements based on these multiple indicators instead of risking an inappropriate inference based on a single variable.

Integrating health data in understanding housing inadequacies will allow for more informed urban planning with the goal to promote healthier cities and living environments. Given the large proportion of residents who live in informal settlements, it is pertinent for policy discussions to understand their needs to equitably serve the city with its limited resources. Looking at health from beyond the clinical determinants allows for more comprehensive plans to be created to address disease burdens which can be alleviated through interventions in social determinants of health. For future research, studies can be conducted to understand the impact of other environmental factors such as outdoor temperature, noise, and weather impacts which can build a better understanding of the housing conditions and living environment. By increasing the length of the study to measure disease incidence across households we can have a better understanding of housing conditions and its impact on cases of infectious diseases and acute respiratory conditions.

The study was conducted in a very short time, with reduced resources which resulted in only two sites being surveyed. The small sample size limited our ability to conduct subgroup analysis which could have had an impact on disease status. Moreover, for an improved study of infectious diseases and acute health problems, a study of incidence rates would have been more appropriate. Questions related to respiratory conditions and infectious diseases were self-reported by respondents which could introduce a recall bias, as some respondents had difficulty recalling health status for other family members. The study areas were limited to only two informal settlements across Dhaka city, however urban regions across the country have different make up in their residential structure and a nationally representative sample would be needed in order to build stronger conclusions.

7. Conclusions

The methods used for developing the HSEH index in this paper support the use of PCA in assessing and ranking households using contextualized variables for Bangladesh. The use of empirical field data ensures that the current understanding of HSEH is based on robust data, which contributes to nuanced understanding of the housing conditions of the households sampled. Our study found significant associations between the HSEH index scores and health outcomes, showcasing a lower score is associated with adverse health outcomes for respiratory conditions, infectious diseases and mental health disorders. These odds are found for these diseases, and associated with 16 different housing dimensions presented in a composite indice.

The quality of living in Dhaka city is continuously deteriorating due to the lack of urban planning, which introduces individuals to long exposures to housing related hazards which have adverse health outcomes. Individual and population health, by extension, is influenced by housing quality, and its inadequacies which pushes for comprehensive approaches to improve public health outcomes in Dhaka city. This study was the first step in identifying disparities in housing quality across informal settlements and assessing which areas of housing quality need prioritization for improvement. As Bangladesh continues to work towards improving health outcomes for its residents, it's imperative to study the living area that they spend most of their time in.

Despite its limitations in a variety of study areas, the study presents itself as a successful pilot to scale the study to a nationally representative sample which will be more useful for national policy discussions. Future studies should also look at longitudinal impacts of housing on health status of individuals, considering more empirical measures of heat and noise in the study to better capture environmental hazards. By designing a longitudinal study to study impacts of housing on health, we can account for the seasonal differences in disease incidence as most infectious diseases (i.e. cholera, diarrhea, dengue, malaria) rise in incidence during monsoon season in Bangladesh.

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9. Annex

Annex Table 1: Variables Used and coding

SL	Independent Variable	Definition	Justification
1	Durable Housing**	Durable materials used for Floor, Walls, and Roof. With no leaking from rooftop	AHI defines durable housing as a household which uses finished and durable materials for floors, walls and roof. An additional component of no leaking from the roof was added, as studies cite roof leaks as structural issues.(Behr et al., 2021; Gentry et al., 2007)
2	Occupancy Status***	Rented or Owned Household	Global studies have found that household ownership as a measure of tenure has showcased, owners and renters have significantly different health outcomes (Tomioka et al., 2019).
3	Overcrowding*	more than 3 people living per room	AHI uses the definition from the widely adopted UN habitat definition for adequate living space to define overcrowding (Behr et al., 2021).
4	Sanitation Access**	Toilet facility is located within the household, not shared by any other household and of improved type.	The AHI recognizes the WHO/UNICEF Joint Monitoring Programme (JMP) definition of adequate access to sanitation as a toilet facility which is not shared between multiple households due to lack of sample. However, the full JMP definition has been adopted in this index (Behr et al., 2021; *Progress on Household Drinking Water, Sanitation and Hygiene 2000-2020*, 2021).
5	Drinking Water Access**	Drinking water is from an improved source, and access is available for more than 22 hours a day.	Sources state that improved water access should be consistent and uninterrupted. To define uninterrupted, water should be available for at least 90% of the day, which is more than 22 hours in a day (DuChanois et al., 2019).
6	Fear of Eviction*	Household members experience fear of eviction by landlord or government	The AHI definition used from the PRINDEX security of housing standard (Behr et al., 2021).
7	Access to Electricity**	Access to electricity is available for at least 22 hours a day, with sufficient power for basic services.	Using the Energy Sector Management Assistance Program definition for the highest tier for electricity access to define sufficient access to electricity (SE4ALL & ESMAP, 2021).
8	Good Indoor Air Quality**	Clean cooking fuel utilized in a ventilated kitchen	Besides use of clean cooking fuel, kitchen ventilation was also studied since even the use of gas instead of solid fuel can result in suspended gaseous contaminants (Nahar et al., 2016).
9	Other Water Access***	Water for other uses comes from a piped source with access	Water for other uses is primarily for cooking and hygiene practices. Sources state that improved water access should be consistent and uninterrupted. To

		available for more than 22 hours a day.	define uninterrupted, water should be available for at least 90% of the day, which is more than 22 hours in a day (DuChanois et al., 2019).
10	Affordability***	Rent or Loan Repayment is less than 30% of total monthly income.	Affordable housing is considered housing payments less than 30% of total household income. Anything above that is considered unaffordable for the purpose of our study (Chowdhury, 2013).
11	Light Needed during Daytime***	Rooms are sufficiently illuminated by natural light during the day	Studies have showcased strong evidence that presence of natural light in households has a positive impact on physical and mental health (Osibona et al., 2021).
12	Waterlogging***	No waterlogging experienced inside the household, or in its immediate vicinity after rainfall	Waterlogging has been studied to increase spread of water-borne and vector-borne diseases such as cholera and dengue, with the availability of contaminated stagnant water (Taufiq, 2021)
13	Damp Walls***	Walls do not remain damp to touch after rainfall	Moisture in the household, felt through damp walls can contribute to an increased incidence of infectious diseases and respiratory conditions (Bornehag et al., 2001).
14	Waste Disposal***	Formal waste collection is practiced with no noticeable smell entering the household	Lack of proper waste management also presents a significant concern due to their ability to contribute to the spread of infectious diseases. Unsanitary conditions created by a lack of proper waste management can lead to contamination of water sources, which can result in an increase in vector breeding and waterborne diseases in the area (Porta et al., 2009; Vinti et al., 2021; Yeboah et al., 2024).
15	Extreme Indoor Temperature***	Room does not get extremely hot during the summer, or extremely cold during the winter	Moreover, without the ability to mitigate extreme indoor temperatures, individuals can experience increased risk of mental health disorders, as well as respiratory conditions (Tham et al., 2020).
16	Ventilation***	Every room in the household has a window	A lack of windows can also impact indoor air quality, as pollutants remain within the household without a fixed method of ventilation having a negative impact on health (Wargocki, 2013).
* Adopted from AHI without any changes. ** Adopted from AHI with modifications *** Additional housing conditions available in literature			

Annex Table 2: Principal components/correlation
Rho = **0.6352**

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.44106	0.603689	0.1526	0.1526
Comp2	1.83737	0.481725	0.1148	0.2674
Comp3	1.35565	0. 081851	0.0847	0.3521
Comp4	1.27379	0.13276	0.0796	0.4317
Comp5	1.14103	0.0283201	0.0713	0.5031
Comp6	1.11271	0.111073	0.0695	0.5726
Comp7	1.00164	0.123399	0.0626	0.6352
Comp8	0. 878243	0.0421064	0.0549	0.6901
Comp9	0.836136	0.0544951	0.0523	0.7424
Comp10	0 .781641	0.106988	0.0489	0.7912
Comp11	0.674653	0. 0287689	0.0422	0.8334
Comp12	0.645884	0.0493974	0.0404	0.8737
Comp13	0.596487	0.0565018	0.0373	0.9110
Comp14	0.539985	0.0144286	0.0337	0.9448
Comp15	0.525557	0.167401	0.0328	0.9776
Comp16	0. 358155	.	0.0224	1.0000

Annex Table 3: Principal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7
Durable Housing	0.3865	0.0700	-0.1611	0.2110	0.1623	0.1306	-0.2493
Affordability	0.0254	-0.2455	0.04217	-0.1754	0.4799	0.0563	0.1643
Overcrowding	-0.1140	0.2457	0.2864	0.2797	-0.1798	0.0136	-0.3278
Fear of Eviction	0.0973	-0.0315	0.2847	0.1467	0.3112	0.6188	0.0089
Sanitation Access	0.0237	0.5223	0.1939	0.2064	-0.1815	0.0500	0.0177
Source of Drinking Water	-0.4605	0.0806	-0.0961	0.2551	0.2693	-0.1058	0.0944
Other Uses of Water Access	0.4697	-00.1155	0.1553	-0.1945	-0.2196	0.0525	-0.0401
Waste Disposal	0.2915	0.3270	-0.0705	-0.0136	0.1579	0.2278	0.0015
Indoor Air Quality	-0.2212	-0.3985	-0.0435	0.1471	-0.0741	0.2524	0.1821
Extreme Indoor Temperature	0.1623	0.1772	-0.0063	0.3149	0.1867	-0.1606	0.6812
Damp Walls	0.2897	-0.2939	0.0799	0.3124	0.0056	-0.0558	-0.0774
Lack of Natural Light	0.0419	-0.2841	0.1294	0.2871	0.2572	-0.4095	-0.4178
Access to Electricity	0.3227	0.0916	0.0833	-0.0768	0.1375	-0.5013	0.1689
Ventilation	0.0360	0.1363	-0.5349	0.1398	0.4216	0.0644	-0.2161
Waterlogging	0.0891	-0.1877	0.0204	0.5933	-0.3270	0.0370	0.1457
Occupancy Status	-0.1871	0.2334	0.4885	0.0310	0.1594	-0.1061	-0.1356