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# Health Dynamics in the Built Environment: An Urban Intensity Perspective – An Exploratory Study in Trinidad and Tobago

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**ABSTRACT:** The built environment encompasses the physical components of the environment, inclusive of infrastructure, households, buildings, streets, and open spaces, within which individuals reside and carry out their daily activities. It affects both indirectly and directly on the outdoor and indoor physical environment as well as the socio-economic environment. The elements which comprise the built environment and those of the physical and socio-economic environments, which are affected by it, are recognised as key determinants of health. In this study, health dynamics in the built environment are explored along the urban-rural gradient in Trinidad and Tobago. The gradient is measured by a statistically validated Urban Intensity Index developed previously, using physical data from the built environment. Published physical health data from National Surveys as well as data collected on perceptions of health care access and environmental quality are utilised in conjunction with the Urban Intensity Index values to model chronic illness. Multivariate statistical analysis and maps are used to explore and illustrate these dynamics. Ultimately, the outputs of this study can potentially support efforts to diminish the gap between rhetoric and reality, through provision of critical information for policy and decision making, as the global development agenda moves towards evidence-based policy making.

**KEYWORDS:** Health, environmental quality, Urban Intensity Index, built environment, multivariate statistical analysis

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## Introduction

The built environment is inextricably linked to the health and well-being of its inhabitants, shaping patterns of health through both direct and indirect pathways. It is regarded as one of the most defining outputs of urbanisation, the global proliferation of which has resulted in health dynamics in the built environment emerging as a critical area for research and policy making.<sup>1,2</sup>

The impacts of the built environment on health are complex. Building and infrastructure design, transportation modes, land-use patterns, and physical environmental quality are the main factors which can directly contribute to critical urban health issues, inclusive of obesity, associated chronic disease conditions, infectious diseases, depression, and cardiovascular and musculoskeletal diseases.<sup>3</sup> Indirect impacts are associated with the influence of elements and design of the built environment on individual behaviour, feelings, and accessibility.<sup>3-6</sup>

The local public health system is challenged by increased demand for health services, occasioned by increased population density, persistence of traditional diseases, the emergence of new diseases (such as the Zika virus), and an increase in non-communicable diseases (NCDs), all within the context of low economic growth and depressed government revenue streams. It is necessary to improve the system by optimising delivery of health services to residents. To achieve this, expansion of the focus beyond the traditional health sector perspectives is required.

One approach seeks to incorporate in the decision-making process an understanding of the influence on health dynamics

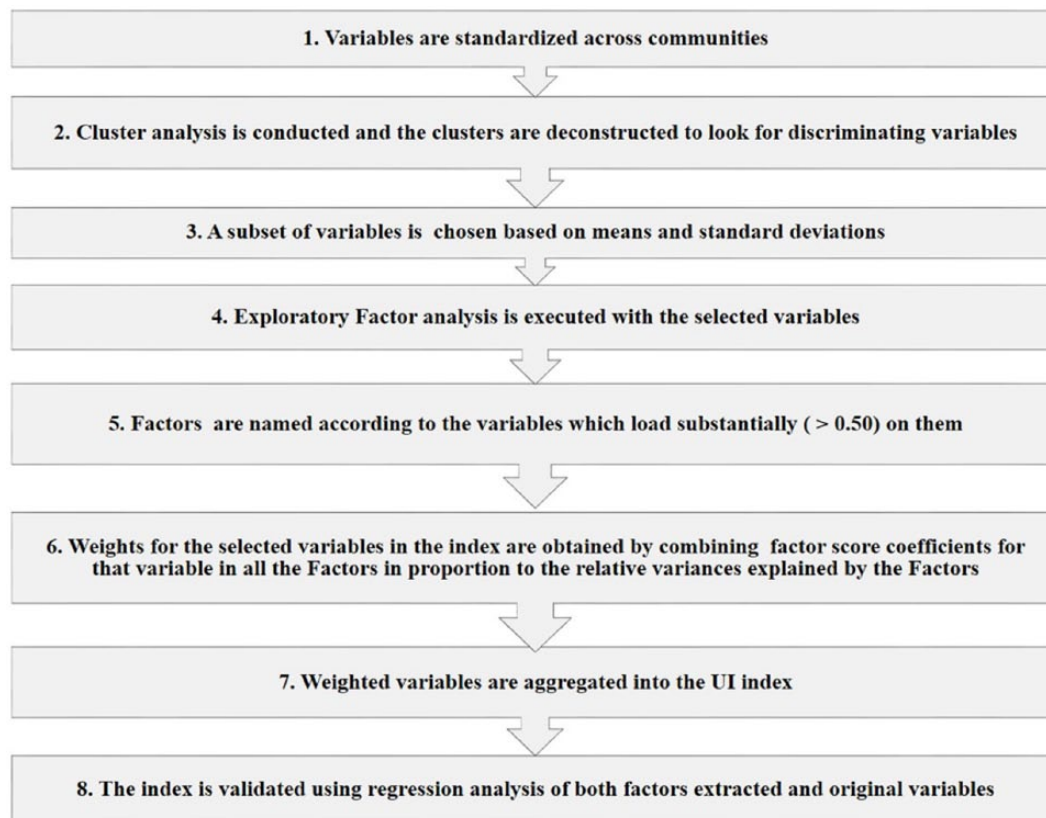
of urbanisation, which is traditionally associated with higher levels of access to and quality of public health services. However, the concomitant challenges of unmanaged urbanisation have compromised provision of key services, inclusive of health, resulting in deficiencies in access across the urban-rural spectrum.

Urban health indices are eminently recognised as important resources which can potentially address urban health management challenges and inform development of evidence-based local policies.<sup>7</sup> Several well-established urban health indices exist such as the Urban Health Index; however, they are predominantly focused on larger geographic areas and are scarce at smaller scales and within the Caribbean region. Although individual core indicators have been identified for the Caribbean and Latin America, the development of methodologies for combining the most relevant indicators into indices remains an area requiring advancement.<sup>8,9</sup> In addition, access to and quality of health services and facilities should be evaluated in terms of their flows to residents. Therefore, perceptions of residents' access and satisfaction with health services need to be understood. A perception index can be a useful management tool as it provides a metric, which facilitates elucidation of the multi-dimensional relationships underlying health care access, environmental quality, and urbanisation.<sup>10</sup>

In this article, a gradient approach is taken in analysing the health dynamics in the built environment, ranging from large-scale built environments within urban centres to small-scale ones within less urban systems. A proprietary Trinidad and



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**Figure 1.** An overview of the *Urban Intensity Index* construction.<sup>11</sup>

Tobago *Urban Intensity Index* (TT UII), developed prior to this study, is utilised as a multivariate descriptor of the built environment. It is used to give context to perception data on health care access and environmental quality collected via an original survey instrument as well as to Census data for area levels of relevant NCDs.

### Trinidad and Tobago's *Urban Intensity Index*

The statistically validated *Urban Intensity Index* (UII) is built systematically from a logical sequence of steps from physical data on the built environment of 581 communities in Trinidad and Tobago. These steps start with reduction of the number of potential variables, selected from the original dataset, to a smaller set of key relatively discriminating characteristics. The most applicable of these are extracted by exploratory factor analysis (EFA) from this reduced variable set as a group of orthogonal latent multivariate factors, which represent the different dimensions of urban intensity. These factors are converted back into appropriately weighted original variables to form an aggregated index, validated by regression analysis, which also permits removal of redundant variables so that the final index is trimmed to relatively independent predictors. The index scores are separated into statistically validated practical classes by discriminant analysis.<sup>11</sup> An overview of the main steps involved in development of the UII is given in Figure 1.

In this study, an 8-category classification of the UII is used. Each class contains communities with index scores within a

specific range. The 8 classes range from 1 which is used for the group of least urban (or most rural) communities to 8 which represents the most urban areas.

### Methodology

#### *Perceptions of access to health care and environmental quality*

A comprehensive survey instrument was designed to capture individuals' perceptions of access in their communities to key ecosystem services. It is comprised of 6 main scales (*Total Access*, *Environmental Quality*, *Positive Environmental Behaviour*, *Freedom, Recreation and Culture*, and *Disturbance*). One of these, *Total Access*, itself has 9 sub-scales, which include *Health Care Access*. The scale items are original and were developed from extensive review of the literature. This article utilises the data gathered on the *Environmental Quality* main scale and on the *Health Care Access* sub-scale from that instrument. All scales on that survey utilised a proprietary 6-point interval scale (0-5). The *Environmental Quality* scale captures the level of concern about environmental issues perceived by respondents as present in the ecosystem. It is comprised of 22 items, which capture negative aspects of Air Quality, Noise, and Land Use components, while the *Health Care Access* sub-scale consists of 9 items, which measure access to different health care services. The structure of the questionnaire and items for the *Health Care Access* and *Environmental Quality* scales are given in Table 1.

**Table 1.** Structure of questionnaire.

SECTIONS	DETAILS
Demographics	11 questions – age, sex, level of education, location (region and community), vehicle ownership, employment (status, type of worker, industry, and occupation).
Scales	Total Access, Freedom, Environmental Quality, Positive Environmental Behaviour, Recreation and Culture, and Disturbance.
Access sub-scales	Education, Employment, Utilities, Health Care, Information and Communications Technology, Commerce and Banking, Transportation, Political Representation, and Safety and Protective Services.
Environmental quality scale items	The air quality in the area where I live is good. Air quality in my area is a matter of concern. Outdoor air quality in my area affects me negatively. The air quality inside my home is good. I suffer from a respiratory illness. Person/persons in my household suffer from a respiratory illness. Poor indoor air quality can contribute to respiratory illness. Poor outdoor air quality can contribute to respiratory illness. Noise is a cause for concern in the area where I live. There is too much noise in my area. Noise affects me often in my area. Traffic in my area is a nuisance. I am unable to carry out certain activities due to noise in the area. Noise in my area often affects my ability to sleep. Indiscriminate dumping of waste occurs often in the area where I live. My area has undergone loss of trees and 'greenery' over the past years. My area has experienced growth in buildings at the expense of trees and 'greenery'. Constructions of buildings in my area receive planning approval. Composition of wildlife within the past years has changed in my area. Wildlife has been negatively affected by the development in the area where I live. The heat in the area has increased in the past years. The humidity in the area has increased in the past years.
Health care access sub-scale items	Public health facilities are conveniently located in the area where I live. The public health facilities which service me meet my requirements. Public health facilities in my area offer services that are of high quality. Medicine needed is available at the public health facilities I use. Private health care facilities are available in the area where I live. Private health care facilities in my community are affordable. Pharmacies are conveniently located in my area. Pharmacies in this area meet my medicinal needs. Medicine needed is affordable at the pharmacies in my area.

*Administration of survey.* The survey was administered online, using Survey Monkey, for a period of 6 months. It targeted residents of Trinidad and Tobago. Using multiple modes, such as email invitations, social media posts, and posts on the University of Trinidad and Tobago's website, individuals were exposed to the survey link and invited to participate, with the incentive to do so being entry into a draw for one of several prizes.

#### *Development of perception indexes*

Perception indexes were constructed for all survey scales using the same methodology as that for the TT UII, summarised previously in the 'Trinidad and Tobago's *Urban Intensity Index*' section. However, with these perception indexes, there is no first step to choose acceptable and reliable variables, as there would need to be with physical data (as is the case with the UII). Instead, the item statements on the perception scale are the variables, which will be aggregated into the index. All of these will not have equal weight in that multidimensional aggregate. The weight of the contribution to the overall index of each different scale item statement can be estimated using

EFA to extract orthogonal factors (and factor scores) from these items. The products of the factor score coefficients and the percentage of variance explained by the factors are used as weights to combine the scores of scale items into the composite index values. This allows only the multidimensional factors, which contribute to the explained variance in the scores of the scale variables, to be incorporated into the index. (Some qualitative corroboration for the usefulness and importance of the contribution to the overall index of different item statements on the scale comes from reliability analysis. The internal consistency of the scale or the reliability with which the scale items represent the underlying complex construct can be estimated by the Cronbach's alpha value. By removing 1 item at a time from the scale and recalculating alpha, one can get an idea of how important each item is to that scale, because removing good items lowers the scale alpha value.)

#### *Chronic illness measure*

Anonymised individual data were obtained for relevant NCDs: cancer, diabetes, asthma, hypertension, and heart disease, from

the 2011 Trinidad and Tobago Population and Housing Census conducted by the Central Statistical Office (CSO). Only individuals who were 18 years of age or older at the time of the Census were included in the analysis. This resulted in the inclusion of 530 013 individuals.

The data were combined into scores for 1 NCD variable. The individual scores for this variable are modelled using logistic regression with demographic variables (sex, ethnicity, age, and education) and the UII class values of the individuals as predictors. Individuals were assigned UII class values based on the community within which they resided.

The goodness of fit of the model was assessed by examining the Pearson chi-square statistic ( $\chi^2$ ), the significance of the predictors, the classification table, and classification plots. Confidence intervals (CIs) for Exp(B) are quoted for each successful predictor.

## Results

### Demographics of respondents

Data from the survey were obtained for 561 participants who resided in various communities within all 14 regional corporations and municipalities in Trinidad and communities in Tobago. The largest number of respondents resided in the North Eastern part of Trinidad within the region of Tunapuna/Piarco while the smallest number resided in Tobago, which generally reflected the geographic distribution of the Trinidad and Tobago population according to the 2011 Population and Housing Census.<sup>12</sup> The majority of the respondents on the survey were women (55.1%). Most of the participants were employed (59.4%) with a preponderance within the age group 18 to 25 (51.7%) and had at least a secondary school education (99%). The majority of employed respondents were government workers (68.2%) in various industries, in particular education (58.8%).

### Reliability of access scales

Reliability analysis was carried out for each scale by estimating the Cronbach's alpha value for the entire scale and for the scale with 1 item at a time removed. An alpha value between .7 and 1.0 is taken to be an acceptable measure of good internal conversion and a sign that the scale is measuring a single latent complex construct. Alpha values for both the *Health Care Access* sub-scale (.88) and the *Environmental Quality* scale (.77) were relatively high. No item on either scale was found to affect negatively on overall reliability.

### Themes of health care access and environmental quality

The orthogonal factors extracted using EFA measure the latent dimensionality of the complex construct captured by each scale. The factor solutions for the scales are given in Tables 2 and 3. The factor names are subjective and reflect the essence of the

**Table 2.** Factor solution for the *Health Care Access* sub-scale.

FACTORS	% VARIANCE EXPLAINED
1. <i>Public Health Care Access</i>	31.9
2. <i>Access to Drugs and Medicine</i>	26.3
3. <i>Private Health Care Affordability</i>	17.4

Kaiser Meyer Olkin (KMO)=0.843, Bartlett's Test of Sphericity,  $\chi^2(36)=2430.4$ ,  $P=.000$ .

**Table 3.** Factor solution for *Environmental Quality* scale.

FACTORS	% VARIANCE EXPLAINED
1 <i>Noise Issues</i>	20.3
2 <i>Land Use and Biodiversity</i>	14.1
3 <i>Air Quality</i>	9.7
4 <i>Heat and Humidity</i>	9.7
5 <i>Respiratory Illness Caused by Poor Air Quality</i>	8.8
6 <i>General State of Air Quality</i>	8.2

Kaiser Meyer Olkin (KMO)=0.816, Bartlett's Test of Sphericity,  $\chi^2(231)=6740.98$ ,  $P=.000$ .

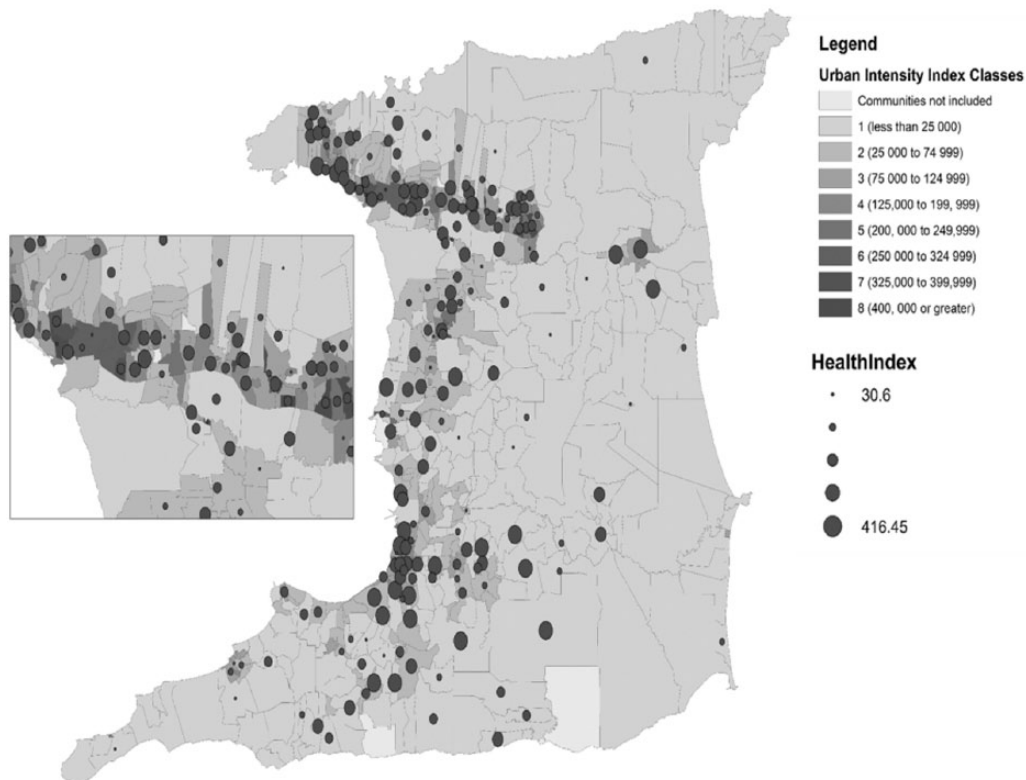
scale statements which load most strongly ( $>.50$ ) on the particular factor. The percentage variance explained by each factor, which is itself an indication of how much that factor contributes to the overall scale construct, is given in the first column. In every case, the elements of a good solution (small Akaike information criterion [AIC] off-diagonal values, significant Bartlett's Test of Sphericity, and Kaiser Meyer Olkin (KMO) statistic values closer to 1.0) were checked and met.

Three orthogonal factors extracted from the *Health Care Access* sub-scale together explained 74.5% of the variance of the scale items. All of the 9 items on this scale loaded substantially onto the factors.

Six orthogonal factors were extracted from responses on the *Environmental Quality* scale representing different dimensions of environmental quality: *Noise Issues*, *Land Use and Biodiversity*, *Air Quality*, *Heat and Humidity*, *Respiratory Illness Caused by Poor Air Quality*, and *General State of Air Quality*. The factors together explained 70.8% of the variance. Two items did not load sufficiently ( $<0.50$ ) on any of the factors: 'Traffic in my area is a nuisance' and 'Constructions of buildings in my area receive planning approval'.

### Environmental quality and health care perception indexes and urban intensity

Pearson product-moment correlation coefficients were estimated for the association of UII scores with the Health Care



**Figure 2.** Distribution of the urban intensity classes and *Health Care Access Index* means in Trinidad.

Index scores as well as with the *Environmental Quality Index* scores. Neither relationship was significant. Although there appears to be no linear correlations between the values of the ecosystem service indexes and those of the UII over the entire range, it is possible that the relationships may follow different models from one UII class to another. Consequently, to gain more insight into the class-by-class differences in perceived health access, the mean community index scores for survey respondents were obtained and shown on distribution maps for the 8 UII classes.

#### *Health care access and UII classes*

The community means of the *Health Care Access Index* were mapped with the distribution of the UII classes as shown in Figures 2 and 3. These maps, along with the scatterplot, given in Figure 4, illustrate the trends in *Health Care Access* with UII classes, among the survey respondents. *Health Care Access* shows a general increase with urban intensity to a maximum in class 5 and then declines in the higher urban intensity classes. The fall-off in health care access, noted in Figure 4, is reasonable in higher urban areas. Within each UII class, there is variability in the level of *Health Care Access* with respondents of some communities perceiving higher levels than others within the same class. A possible explanation for this could be that some individuals are better able to access quality private health care as well as transportation due to their incomes. Respondents, who live within distinct clusters of communities of higher urban

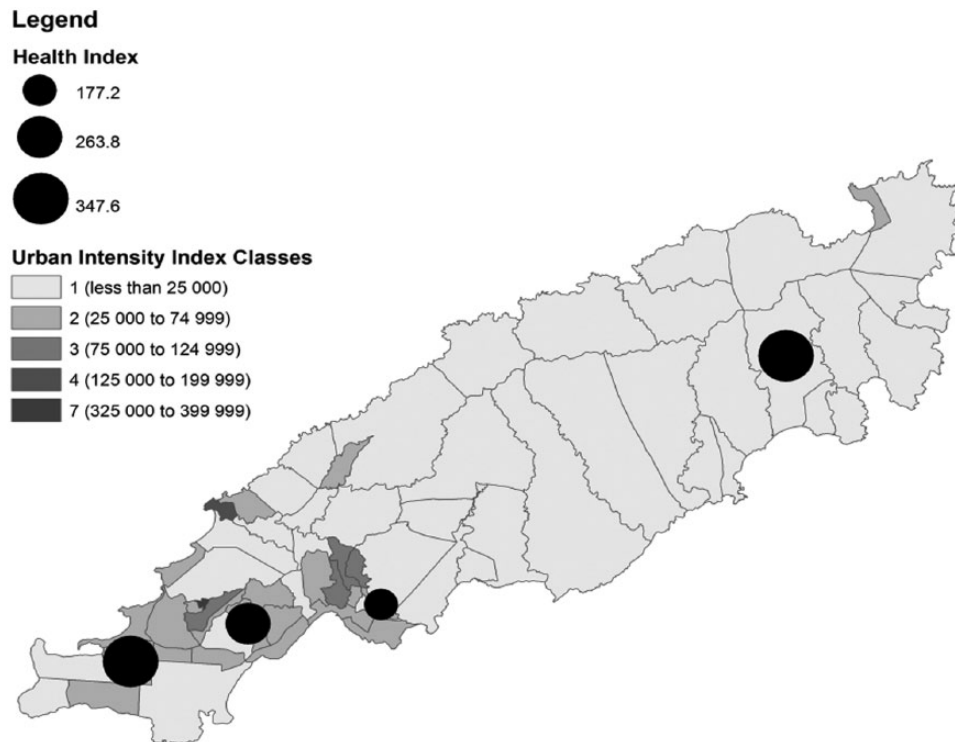
intensities within more rural surrounding regions, generally perceived higher levels of health care access than those in the less urban communities within the same region. This is most notable in the region of Sangre Grande located in the north-western quarter of Trinidad.

To further explore the patterns of health care access among respondents with urban intensity, the orthogonal factors extracted during EFA for this scale were mapped with UII classes. Due to a very small number of communities and respondents sampled from Tobago, the *Health Care Access* factors were mapped for Trinidad only and shown in Figures 5 to 7.

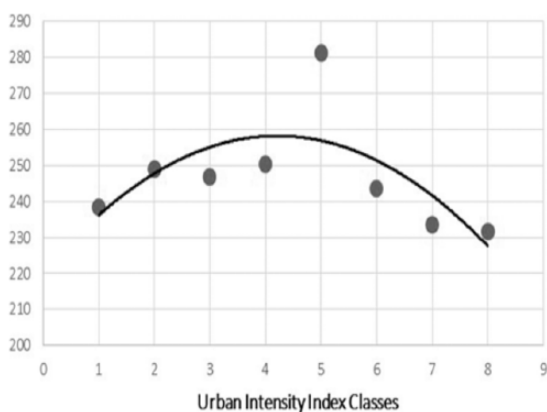
For all *Health Care Access* factors, as observed with the values for the overall index, there is variability in perceptions of access within each UII class. A relatively high percentage of respondents, who resided within communities of high UII classes, perceived lower levels of *Public Health Care Access* compared with those who resided within less urban communities (see Figure 4). This contrasts with what is observed for the other 2 factors, *Access to Drugs and Medicine* and *Private Health Care Affordability*, where higher percentages of respondents from more urban communities than those from more rural areas perceived higher levels of access to drugs and medicine and felt that private health care was more affordable (see Figures 5 and 6).

#### *Environmental Quality Index and UII classes*

The community means for the *Environmental Quality Index* were mapped along with the distribution of the UII classes, as



**Figure 3.** Distribution of the urban intensity classes and *Health Care Access Index* means in Tobago.



**Figure 4.** Scatterplot of *Health Care Access* means with *Urban Intensity Index* classes.

shown in Figures 8 and 9. These, along with a scatterplot of index means across urban intensity classes given in Figure 10, are used to gain insight into the patterns of perceived environmental quality with urban intensity. The means increase to class 4 and then drop a bit, levelling off in the later classes. Class 6 is an outlier with an unusually low mean of 146.5. As mentioned before, this index registers the level of concern about environmental issues in the ecosystem, so higher values suggest a poorer perceived environmental quality. The trend observed suggests that the worst mean quality is perceived to be in class 4 ( $M=181.7$ ), with that in the later classes, 5, 7, and 8, being only marginally better. Standard deviations are quite similar across the classes. They are, however, very high with coefficients of variation in the range 40% to 50%, making this

a highly variable index in terms of responses. This is further supported by what is observed in Figures 8 and 9, which show high levels of variability in perceptions of environmental quality within any given UII class. However, the least urban class (class 1) appears to have the least variability. Generally, though respondents within more urban communities reported poorer environmental quality (high index values) than those who resided within less urban communities.

#### *Logistic regression model for susceptibility to NCDs predicted by urban intensity*

A variable was created with values of '1' or '0' representing whether an individual in the Trinidad and Tobago population suffered (1) or not (0) from one or more of a collection of NCDs, including diabetes, cancer, asthma, hypertension, and heart disease. This variable was modelled using the UII class, the *Health Care Access Index* score, the *Environmental Quality Index* score, sex, age, ethnicity, and level of education as predictors. In this model, the characteristics of health care access and environmental quality are connected to the communities within which the individuals resided, using community means obtained from those communities (218) with individuals sampled in the perception survey, described in the 'Demographics of respondents' to 'Environmental Quality Index and UII classes' sections.

As the NCD variable is a discrete and dichotomous one, which measures presence of an NCD in individuals, binary logistic regression was used to estimate a model. It should be noted that this approach cannot comprehensively capture all of

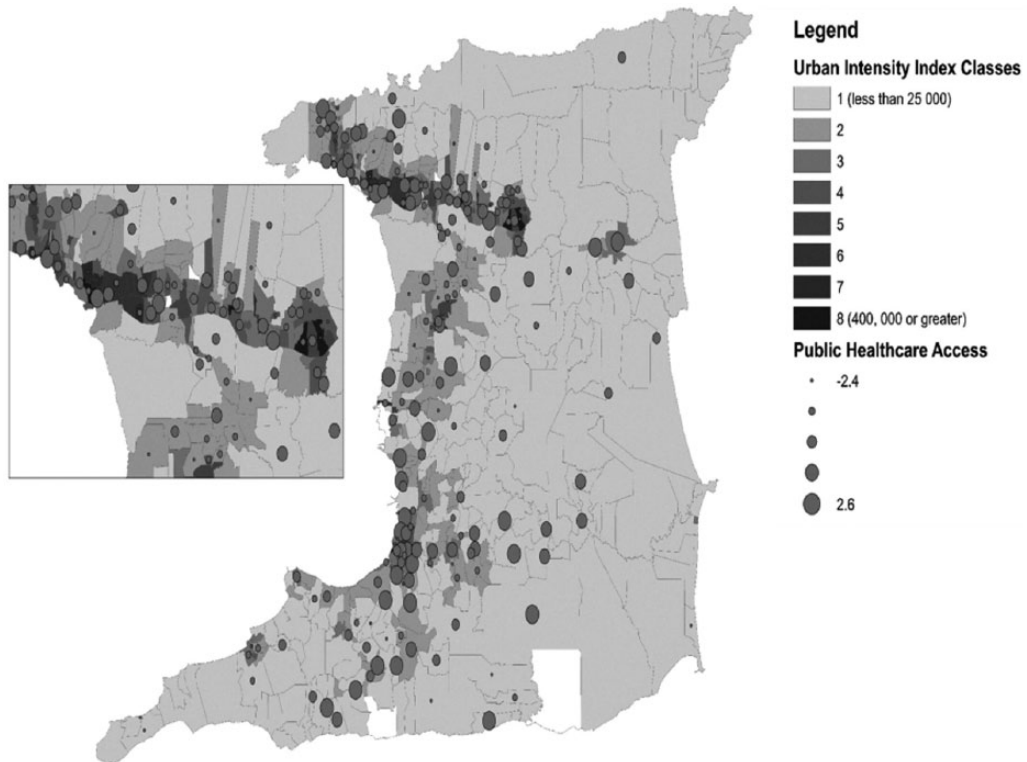


Figure 5. Public Health Care Access among respondents with urban intensity classes.

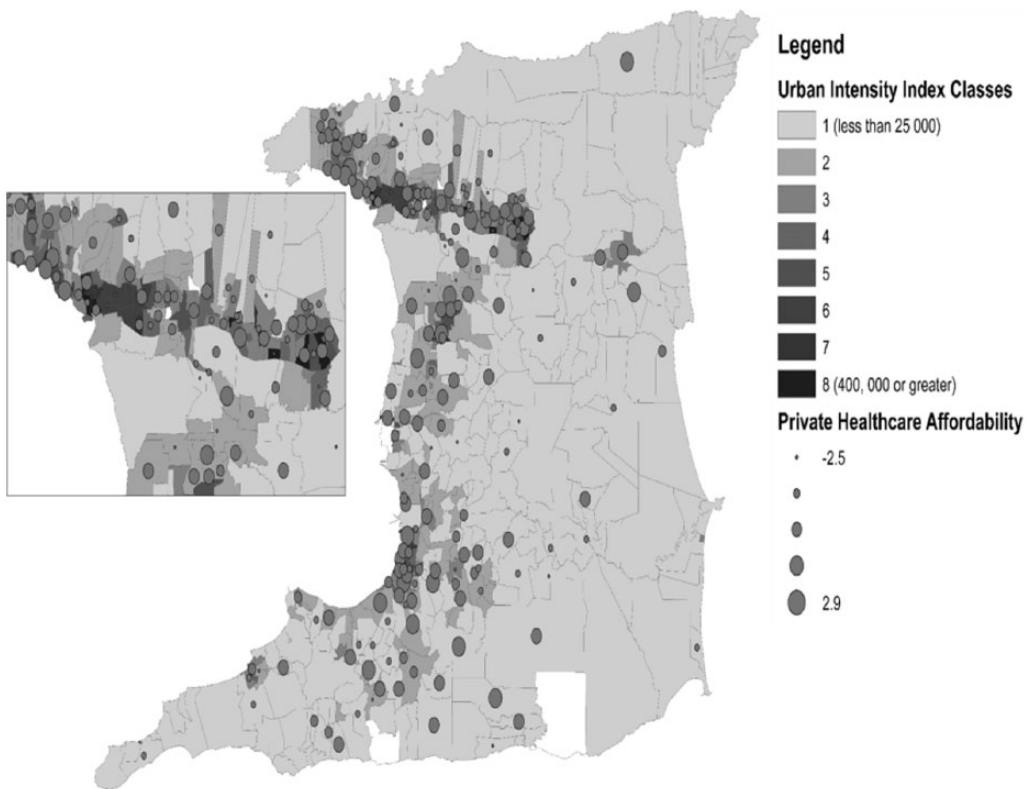


Figure 6. Access to Drugs and Medicine among respondents with urban intensity classes.



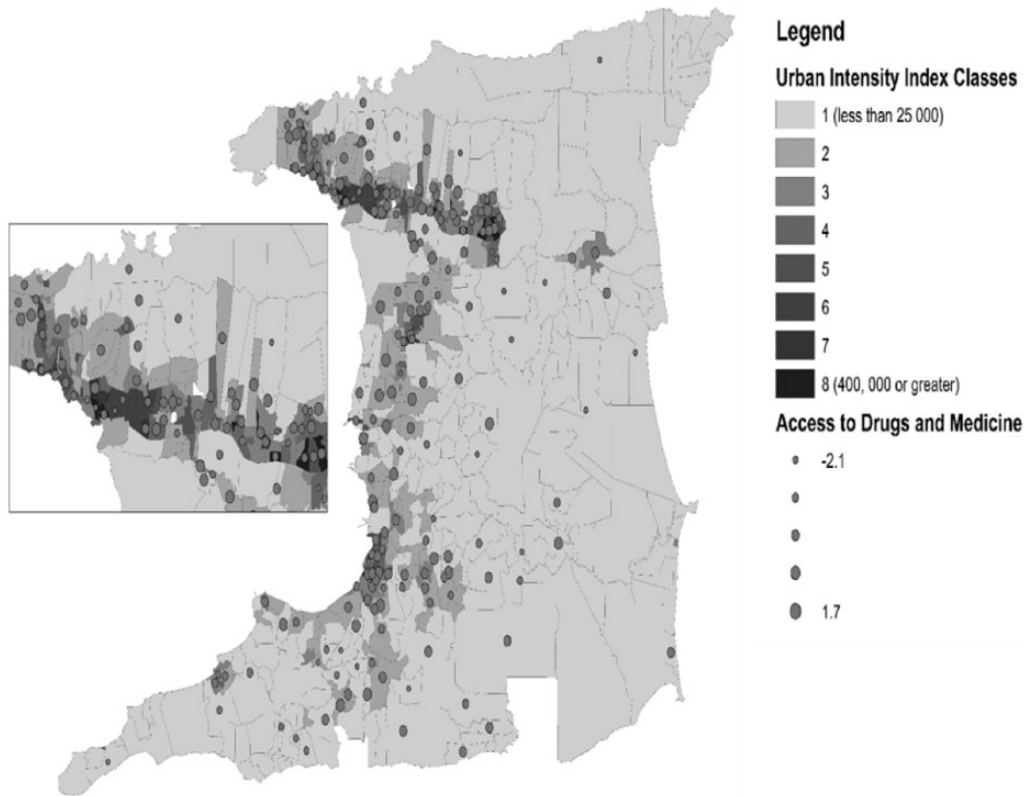


Figure 7. Private Health Care Affordability among respondents within urban intensity classes.

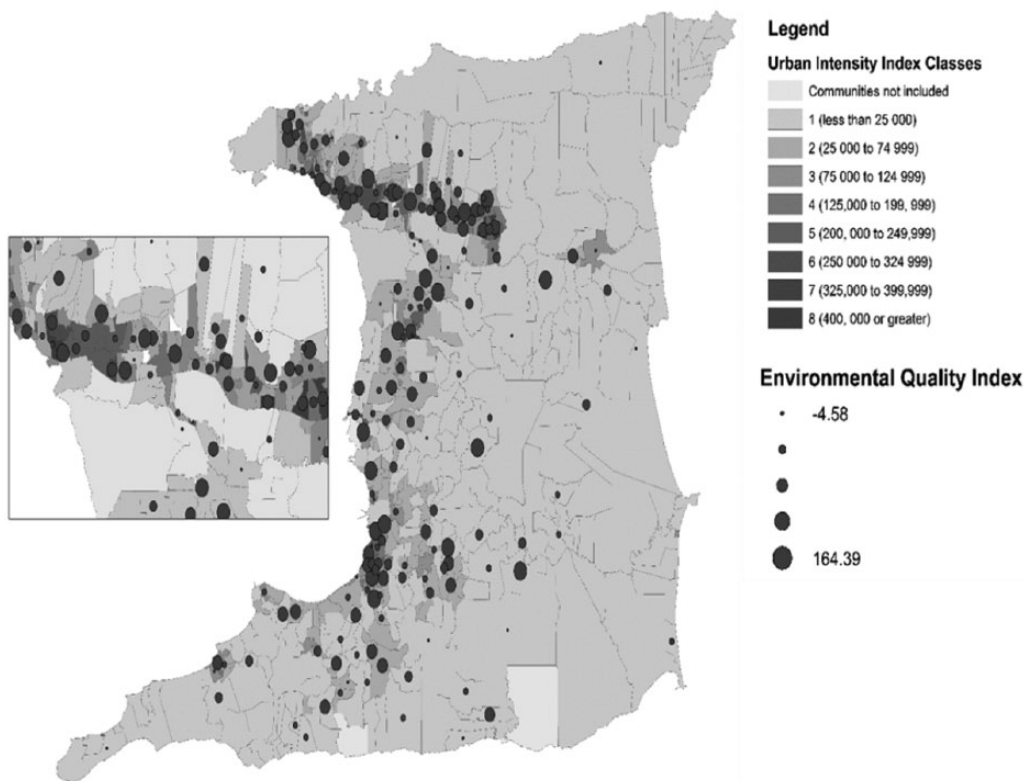
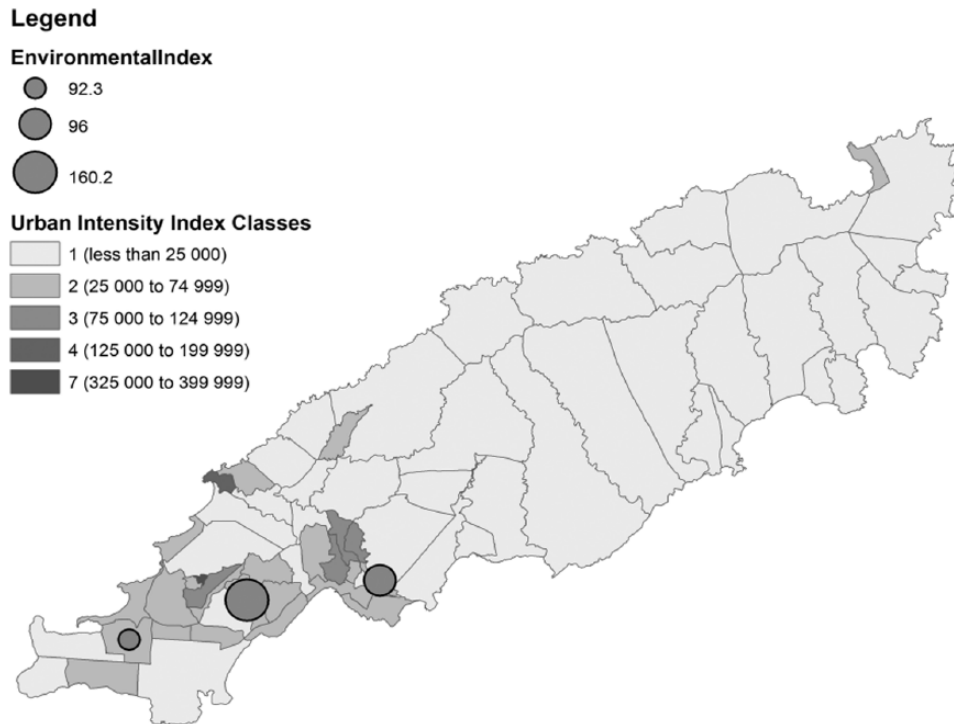
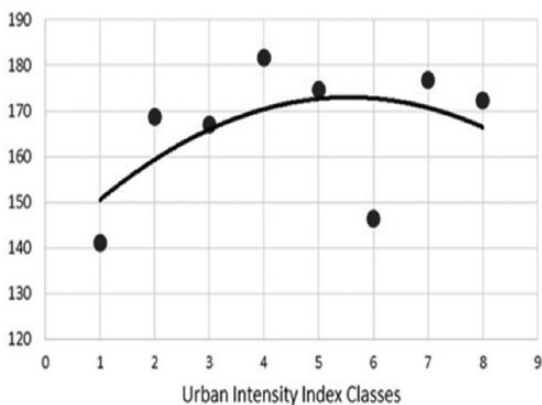


Figure 8. Distribution of the urban intensity classes and Environmental Quality Index means in Trinidad.



**Figure 9.** Distribution of the urban intensity classes and *Environmental Quality Index* means in Tobago.



**Figure 10.** Scatterplot of *Environmental Quality Index* means with *Urban Intensity Index* classes.

the critical determinants of NCDs which include genetic and lifestyle factors. Hence, although the overall model is significant ( $P < .01$  for  $\chi^2$ ), the fit, as seen from the pseudo- $R^2$  values quoted in Table 4, indicates that there is some missing information in terms of other factors which could influence chronic disease susceptibility.

The logistic regression results are given in Tables 4 and 5 as well as in Figure 11. The overall model, as stated above, was found to be significant, Model  $\chi^2(18) = 62012.143$ ,  $P < .01$ , and therefore predicts, significantly better than chance, whether an individual from Trinidad and Tobago, with certain values of the characteristics in the model, is likely to suffer from an NCD. Table 4 shows the significant predictors which were included in the final model. Reference categories are given for all categorical variables with more than 2 classes. These

reference categories are highlighted in grey. For the variable 'sex', the category 'men' is compared with 'women' as the reference. Age, level of education, ethnicity, sex, UII class, and the *Environmental Quality Index* community mean score were statistically significant ( $P < .01$ ). However, the *Health Care Access Index* community mean score was not significant ( $P > .05$ ).

With each successive year of age after 18 years, the odds ratio of having a chronic disease rises by 1.06. Individuals with no education actually have their odds ratio for getting a chronic disease decreased by between 0.78 and 0.88 compared with the reference category, which is the group of individuals with a tertiary education. However, as an individual starts to acquire some education (primary and secondary categories), the odds ratio, compared with the tertiary education reference, actually increases by 1.63 to 1.74 (primary) or 1.15 to 1.23 (secondary).

East Indians are the most susceptible ethnic group to chronic disease, with the highest odds ratio increase (1.75-2.08) from the reference category ('other ethnic group' consisting of Whites, Chinese, Syrian/Lebanese, or any individual not identified as one of the named categories). The odds ratios of the named ethnic groups, which are compared with the reference, can in turn be compared with each other. Ethnically African (1.14-2.36) and Mixed (1.24-1.45) individuals have smaller increases (compared with the reference category) in their odds ratios for chronic illness susceptibility than do East Indians. Men in Trinidad and Tobago are significantly less likely (odds ratio decrease is 0.67-0.69) to have a chronic disease than women (the reference category).

The most urban group, UII class 8, is the reference category. Individuals of every other class, except class 6, have decreased

**Table 4.** Predictors included in the logistic regression model.

PREDICTORS	B	SE	WALD	DF	SIGNIFICANCE	EXP(B)	95% CI FOR EXP(B)	
							LOWER	UPPER
EQ index	0.000	.000	7.478	1	.006	1.000	1.000	1.000
Tertiary	Reference		1930.982	4	.000			
No education	-0.193	.030	40.403	1	.000	0.824	0.776	0.875
Primary	0.523	.017	966.061	1	.000	1.686	1.632	1.743
Secondary	0.175	.016	117.560	1	.000	1.191	1.154	1.230
Post-secondary	0.222	.020	122.893	1	.000	1.248	1.200	1.298
Age (years)	0.054	.000	33222.697	1	.000	1.055	1.055	1.056
Other ethnicity	Reference		1864.467	3	.000			
African	0.222	.045	24.292	1	.000	1.248	1.143	1.363
East Indian	0.646	.045	206.196	1	.000	1.908	1.747	2.084
Mixed	0.302	.045	44.458	1	.000	1.353	1.238	1.479
UIIGROUP(8)	Reference		115.640	7	.000			
UIIGROUP(1)	-0.134	.025	29.276	1	.000	0.874	0.833	0.918
UIIGROUP(2)	-0.077	.023	10.821	1	.001	0.926	0.884	0.969
UIIGROUP(3)	-0.163	.024	45.130	1	.000	0.850	0.810	0.891
UIIGROUP(4)	-0.160	.024	43.041	1	.000	0.852	0.812	0.894
UIIGROUP(5)	-0.086	.026	11.384	1	.001	0.917	0.873	0.964
UIIGROUP(6)	-0.048	.026	3.528	1	.060	0.953	0.907	1.002
UIIGROUP(7)	-0.154	.031	24.659	1	.000	0.857	0.807	0.911
MEN	-0.389	.009	1978.079	1	.000	0.677	0.666	0.689
Constant	-4.479	.056	6321.158	1	.000	0.011		

Abbreviations: EQ index, *Environmental Quality Index*; UII, *Urban Intensity Index*.  
Pseudo-R<sup>2</sup>=0.13 (Cox & Snell), 0.22 (Nagelkerke), Model  $\chi^2(18)=62012.143$ ,  $P < .01$ .

**Table 5.** Classification table.

OBSERVED		PREDICTED		PERCENTAGE CORRECT
		NO CHRONIC ILLNESS	CHRONIC ILLNESS	
Chronic illness	No chronic illness	581 211	43 150	91.5
	Chronic illness	89 055	42 235	37.0
Overall percentage				81.9

a. The cut value is .35.

odds ratios of getting a chronic disease. Groups 3 and 4 (both with CI range for the decrease=0.81-0.89) have the largest odds ratio decreases. The trend seems to be that the odds ratio decreases with urbanisation up to a point (group 4), then increases as urbanisation increases to a maximum in group 5, with the highest odds ratio increase, after which, in group 7,

there appears to be a small decline in the odds ratio of having a chronic disease. Group 6 is not significantly different at the 5% critical level ( $P > .05$ ) from the reference group 8.

The *Environmental Quality Index*, although significant, has an odds ratio increase of 1.000 ( $B=0.000$ ), with zero apparent range in the CI. It should be noted that the values are given to

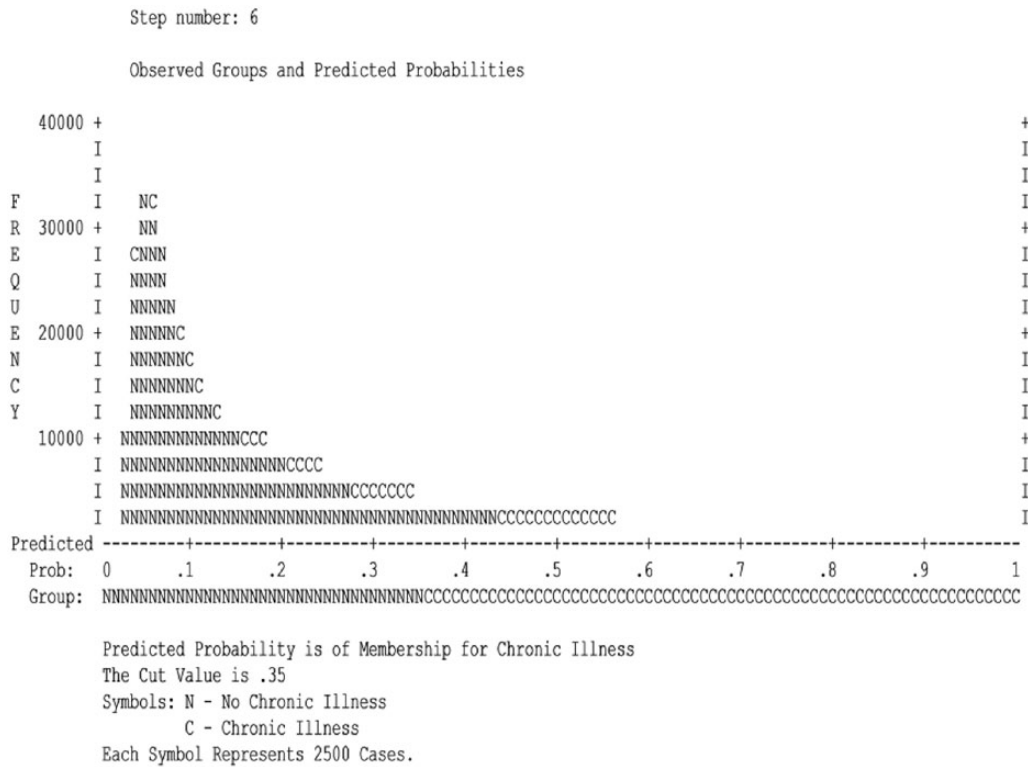


Figure 11. Classification plot.

only 3 decimal places and are not actually 0 or 1, because the *P* value does indicate that this is a significant factor. As environmental quality concerns increase (as measured by the *Environmental Quality Index* community means), the odds ratio of having a chronic illness does increase significantly, albeit only minutely except for the larger changes in the predictor *Environmental Quality Index* mean score itself.

The *Health Care Access Index* was not a significant predictor of NCD and consequently was not included in the final model.

The classification results are given in Table 5. The current model correctly classifies 91.5% of individuals who do not have an NCD and 37.0% of cases (individuals) with an NCD. The overall accuracy of the classification, which is the weighted average of these 2 values, is 81.9%. Originally, with no predictors in the model (just the constant), the overall accuracy was 82.5%. However, that model classified correctly 100% of cases with no NCD and did not classify correctly any cases with NCD (0%). The expanded model significantly improves classification of individuals with an NCD (now 37.0%), with only a small reduction in correct classifications of individuals without an NCD (now 91.5%). The correct and incorrect predictions are illustrated in the classification plot given in Figure 11. This plot is a histogram of predicted probabilities of an individual with an NCD. Note the classification table is shown for a cut value of 0.35, the predicted probability separating the individuals with chronic diseases (C) against those without (N). This cut value is lowered from the system default of 0.5, because the histogram of predicted probabilities for the cases in

the sample shows that at 0.5, there would be far more misclassifications of those with chronic diseases.

### Discussion

The *Healthcare Access* and *Environmental Quality* indices exhibit similar patterns with urban intensity, both generally increasing with urban intensity to a point and then decline as urban intensity increases. The trend in health care access may be indicative of increased competition for health facilities, which are under strain both from high population density and victims of crime, which are more prevalent in urban areas. For *Environmental Quality*, which is an index of environmental quality concerns, this trend is expected as urban intensity increases the myriad adverse environmental impacts associated with urbanisation, such as indoor and outdoor air pollution, noise pollution, poor sanitation, and water quality.

Sex, age, ethnicity, education, *Environmental Quality Index*, and *UII* were significant predictors in the logistic regression results, which modelled the presence of NCD. The odds of having a chronic disease increases with age as expected; however, individuals with no education have decreased odds ratio for chronic disease. One possibility for this trend may be that uneducated individuals usually engage in more manual labour and have less sedentary lifestyles. Some amount of education, by comparison, seems to promote lifestyle choices, which raise susceptibility to chronic diseases, possibly without the ability to afford expensive gym memberships which, the more economically secure, usually those with a tertiary education (reference category), can use to sustain better health.

There is a general decrease in odds ratio for having an NCD with increasing urban intensity up to class 4 after which the odds ratio increases in the higher classes except the second highest urban intensity class (class 7) where the odds ratio declines. These results reflect the nuances of urbanisation and is an expected pattern given competing and opposing effects with urbanisation, namely, decreasing environmental quality but increasing access to health care services. This is corroborated by patterns of the *Health Care Access* and *Environmental Quality Index* behaviour with increasing urban intensity, described earlier.

As environmental quality concerns increase (as measured by the *Environmental Quality Index* community means), the odds ratio of having a chronic illness increases marginally but is statistically significant. A possible explanation for this is the role of other factors, such as genetics, lifestyle, education, and income levels, in attenuating the influence of environmental quality on the likelihood of developing an NCD.

The *Health Care Access Index* was not a significant predictor of NCD. This could be attributable to the fluid nature of the boundaries of many communities in the country, which allow individuals to have access to private and public health care facilities and to medication available in other communities, even if they perceive deficient health care access within their own communities. Another possibility is that the *Healthcare Access Index* does not necessarily reflect the extent to which individuals actually seek out and utilise health care services that are available to them.

## Conclusion

The UII was utilised as a multivariate descriptor of the built environment and demonstrated its continued utility in understanding the impacts of the built environment on both perception data and Census data on NCDs.

Individuals' perceptions of their access to health care and their environmental quality concerns were captured via 2 scales on an original survey instrument, which was administered online. Exploratory factor analysis conducted on the survey scales revealed the latent themes for each and perception indexes were developed from each scale, as for the UII, as the weighted average of factor scores using the variance explained by each factor as its weight in the overall average.

These perception indexes were used in conjunction with the UII to elucidate patterns of health care access and environmental quality concerns across urban intensity classes. The results are indicative of an urban intensity threshold of influence. Initially perceived health care access increased with urban intensity to a maximum and above this threshold experienced a decline. In addition, there was variability in perceived health care access among all UII classes. The patterns observed for environmental quality with urban intensity mirror what is observed for health access, although in this case higher *Environmental Quality Index* values are indicative of more environmental concerns.

Key demographic determinants of NCDs, the UII class, the *Health Care Access Index*, and the *Environmental Quality Index* community means were tested as predictors of susceptibility to NCD. Sex, age, ethnicity, education, *Environmental Quality Index*, and UII were significant predictors in the model.

This study makes a significant contribution to expanding the limited knowledge base of the impacts of urbanisation on health and environmental quality concerns in Trinidad and Tobago. It provides insight into the nature of the influence of demographic characteristics, environmental quality concerns, and access to health care on the prevalence of NCD. While most of the observations made for demographic determinants (sex, age, ethnicity, education) of health were consistent with global trends, environmental quality concerns and health care access trends with urban intensity reflect the nuances of urbanisation within the context of Trinidad and Tobago, indicative of the possibility of an urban intensity threshold for these.

The study is novel in its approach by its utilisation of perception data. National health statistics and physical environmental data alone do not provide a comprehensive picture of the quality, access to, and trends of these services. Perception data better reflect the attitudes and ways individuals internalise their environmental quality and health care access.<sup>13</sup>

In addition, the approach provides a pathway by which the challenges of this type of research may be overcome, as it may not be possible, due to time and economic constraints, to collect physical data at a micro level in many countries. Existing physical data do exist but at broader levels and do not facilitate the analysis in this study.

Some bias was expected in the study due to the online survey administration, which resulted in respondents who were computer literate and had access to Internet service; however, the geographic distribution was generally consistent with Census data, and Internet access is widely available throughout most of Trinidad and Tobago.

This exploratory study identifies possible areas for future research into health dynamics and urban intensity inclusive of a face-to-face survey to capture individuals who do not have Internet access and are not computer literate, as well as studies that can provide insight into the underlying relationships that drive some of the trends. In addition, the importance of studies, which can produce physical environmental data, is recognised. These data can be used in conjunction with perception data to enhance insight into the health dynamics in the built environment.

The results elucidate trends that policy makers and health sector decision makers should be cognizant of and highlight the need for integrating urban planning in optimising the health sector. This is particularly important in Trinidad and Tobago, a developing country, where one of the stated directions by government development plans is to improve the quality and delivery of health care and to address the increasing prevalence of NCDs.

### Author Contributions

Conceived and designed the experiments: SC. Analyzed the data: SC and VS. Wrote the first draft of the manuscript: SC and VS. Contributed to the writing of the manuscript: SC and VS. Agree with manuscript results and conclusions: SC and VS. Jointly developed the structure and arguments for the paper: SC and VS. Made critical revisions and approved final version: SC. All authors reviewed and approved of the final manuscript.

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