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ASSESSING THE ENVIRONMENTAL IMPACTS OF URBANIZATION IN SIDDHARTHANAGAR, NEPAL

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Assessing the Environmental Impacts of Urbanization in Siddharthanagar Nepal

BY

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THESIS

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Dedication

To the unyielding researchers;
and to everyone who is saving lives in the Corona pandemic.
and
to my wife, Prakriti
and to my family and friends.

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Abstract:

Rapid and haphazard infrastructural expansion often contributes to large negative externalities in cities. Environmental problems like air pollution and degradation of quality-of-life elements in an urban settlement are attributed to urban sprawl. Evidence based planning tools need to be developed which can help manage the rapid urbanization that is taking place in the developing world. In this context, we examine the relationship between health outcomes and the different spatial- temporal aspects of an urban-built environment in Siddharthanagar Metropolitan City which is a major settlement in southwestern Nepal. We attempt to identify the aspects of built environment which are closely associated with the exacerbation of a chronic lung condition, COPD. This study has been modeled in the context of developing world cities, it investigates and formulates a possible technique of assessing urban environment.

Keywords: Urbanization, Public Health, Built environment, GIS

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CHAPTER 1

Introduction

1.1 Urbanization, Environment and Health in Developing Countries

Urbanization is a recent phenomenon in human history and is unique to the past few centuries. Prior to 1600, the estimated share of the world population living in urban settings was less than 5 percent; after 1600, the number reached 7 percent in 1800, and 16 percent by 1900 (Ritchie & Roger, 2018). In 1950, the population living in urban areas was 30 percent, which increased to 55 percent by 2018. (United Nations, 2018). In 2050, it is projected that 68 percent of the world's population will live in an urban setting (Ritchie & Roger, 2018). The beginning of this increase was partially due to the fact that building projects could be carried out faster after the Industrial Revolution, which allowed for mass-produced building materials. Economic development and technological advancement enabled people to alter a landscape on a grander scale. Later, it was possible for urban-mega cities such as Shanghai to be built in a matter of a few decades (Taylor, 2013). This study seeks to clarify the relationship between urbanization and socioeconomic-growth, particularly the built-in environment and health aspects of urbanization. Nothing else presents as many opportunities for socio-economic growth as urbanization, which is why it deserves the urgent attention of policymakers, academics, entrepreneurs, and reformers (Fuller & Romer, 2014).

In urban design and planning, the construct made for human settlement and use is often referred to as the built environment. The built environment includes buildings, roads, and parks created by people (Srinivasan et al., 2003). It impacts physical and social environments which subsequently affects health and quality of life (Sallis et al., 2009). Different physical aspects of the built environment such as the distribution of open areas, population density, the density of houses, traffic conditions and number, and the nature of factories can contribute to the quality of urban living.

In developing countries, where the environmental aspects of infrastructural development are not carefully assessed, hurried urbanization can pose serious challenges to the environment and overall livability of the settlement (Chen, 2007). Urban development in developing countries can suffer from unpriced or underpriced externalities such as air pollution, noise pollution, contamination from waste disposal, and traffic congestion (Henderson, 2002). Urban areas are also most vulnerable when there is an outbreak of an infectious disease such as the current and ongoing current, Covid-19 pandemic. A relatively small number of studies have examined the relationship between environmental, ecological, and social-economic changes caused by urbanization. (Chen et al., 2010). The densely populated settlements in cities can have a big health care cost associated with any environmental disturbance. The future needs innovative, resilient and better-prepared cities.

Nepal is one of the ten least urbanized countries in the world, yet in the 2014-2050 period, it is projected to be one of the top ten fastest urbanizing countries (UN DESA, 2014). In 2011, the number of urban centers increased from 58 to 217 (CBS 2014). By 2017 more than 50% of the total population lived in urban centers (MoFALD 2017). The speed and scale of urban transformation can present various challenges such as risks to the immediate and surrounding environment, and to natural resources, health conditions, social cohesion, and to individual rights (Cohen, 2006). As a result of rapid uncontrolled urbanization, metropolitan areas in Nepal have suffered badly from air pollution; that is, haphazard development projects have exposed people to serious airborne diseases (Saud & Paudel, 2018).

People with chronic lung conditions are especially vulnerable to the adverse effects of polluted air (Sint et al., 2008). Chronic Obstructive Pulmonary Disease (COPD) is one of the most serious respiratory diseases globally, which imposes significant financial burdens on society (Ko & Hui, 2009). In 2017, COPD was the second leading cause of all deaths and the third leading cause of disability in Nepal (Nepal, 2017). Systematic meta-analysis of research confirms short-term exposure to air pollution can significantly increase the risk for COPD exacerbations (Li et al., 2016). COPD morbidity has been used as an indicator of how the urban form may interfere with the disease's severity (Monteiro et al., 2012). Tracking COPD admissions with a spatial and temporal reference can possibly suggest areas most affected by increased levels of air pollution. This study examines the occurrence of Chronic Obstructive Pulmonary Disease (COPD) in a southwestern city in Nepal, Siddharthanagar, and attempts to find out what aspects of the urban built environment significantly correlates with this respiratory impairment in order to assess the impact of urbanization in the context of a developing country. This study uses linear regression model to predict the significance of built aspect of urban environment in health, through COPD outcomes, and additionally use Spatial Models to check the accuracy of the results.

This study investigates on different aspects of the built environment and attempts to find if these attributes have significant impact on public health outcomes. The study aims to contribute to developing evidence-based, specific, and quantifiable indicators of assessing an urban-built environment and highlights methodological issues and challenges in developing such indicators. This study investigates a major urban region in southwestern Nepal as a case for the study of developing indicators of the built environment, which can help assess the health impacts in urban settings. These methods may be relevant and applicable to a similar scale of settlements and could be modified for use in other developing countries for the assessment of the urban-built form.

1.2 Siddharthanagar: Study Site Background

Siddharthanagar is a historic city in the southwestern Terai region of Nepal, situated on the border between Nepal and India. This city took its name from Prince Siddhartha, who was born in this region in 563 BCE, and who later became famously known as Gautam Buddha. It is a gateway town to a world heritage site Lumbini. Siddharthanagar therefore is also a major tourist attraction in Nepal. In 2017, it was the destination of 16.7 percent of tourists to Nepal (Anmol, 2018). After Nepal's transformation from a monarchy to a democratic republic in 2008, Siddharthanagar was recognized as a major city in western Nepal. Siddharthanagar has been rapidly urbanizing in past few years. after Nepal transformed into a federal system, Siddharthanagar was recognized as a major city in western Nepal. One of the biggest national highways has been constructed there, the only other international airport in Nepal, besides the one in the capital city Kathmandu, is under construction in Siddharthanagar.

The southern plain of Nepal along which Siddharthanagar is located is referred to as the Terai belt, which is an alluvial flood plain with a hot and humid climate. The Terai region is rich in biological diversity, and is endowed with a variety of flora and fauna including a large range of insect species and aquatic life. These plains and their wetlands provide breeding grounds for many species of migratory birds that arrive every winter when the northern hemisphere freezes from as far as Serbia. This region is also equally favorable for human settlement; and its cities are expanding at a rapid pace. The resulting river and surface water pollution is also causing habitat loss and thus endangering many animal and plant species in Terai.

Siddharthanagar Municipality has 13 wards and has an area of 36 square kilometers. The city is one of the major ports of entry via land from India into Nepal; the majority of imported goods and thousands of tourists enter Nepal via this port. The settlement in Siddharthanagar has largely developed along roadways; in July 2014, a roadway expansion project was commissioned which cleared out the buffer that existed between the existing houses and the roads. The existing belt of trees and smaller vegetation on either side of the road was removed to accommodate the road expansion. This roadway named Siddharthanagar Highway is now 50m wide and has been constructed as close as 3 meters from existing houses. The road expansion project completed in May 2017. It is likely that this infrastructural intervention will have an adverse health impact on the residents of Siddharthanagar. Living near highways has been linked to the potential of developing diseases including respiratory, cardiovascular, birth defects, developmental and neurobehavioral disorders, and can contribute to leukemia (Pearson et al., 2000; Wilhelm and Ritz, 2003; Finkelstein et al., 2004; Gauderman et al., 2005; McConnell et al., 2006; Adar and Kaufman, 2007; Samet, 2007; Samal et al., 2008; Chakraborty, 2009). Environmental studies have shown that the quality of air has seriously depleted in recent years, studies revealed PM2.5 and PM10 concentrations exceeding the WHO guideline around Siddharthanagar, there is significant health risks for the residents and visitors (Rupakheti et al., 2017).

The construction of this highway through the busy settlement has triggered the need to assess the impact that urban built environment can have on human health. It was not immediately known how the physical built environment has been correlated with COPD; this study has set metrics which include the open spaces, built-up area, area of roads, population density, and the number of factories. These different aspects of the urban built environment when regressed with COPD occurrence can reveal the correlation.

CHAPTER 2

Literature Review

2.1 Urbanization in Developing Countries

Countries that are developing economically rely largely on human capital to boost their economic growth. Education and health are two factors that have a substantial impact on human capital. Educated and healthy individuals can work efficiently, and as such earn more. Incidents of disease outbreaks reduce the ability to work productively and also hinders human capital formation. At the beginning of the 20th century, it was formally acknowledged that the planning of cities impacts the health of residents in their responses to outbreaks of communicable diseases (Snow, 1855). The relationship between the built environment and health has become an emerging research topic, as it has been correlated with several health conditions, including obstructive pulmonary diseases, obesity, birth outcomes, mental illness, and morbidity (Sarkar et al., 2019).

Air pollution is a common problem in urban areas in developing world countries. Air pollution problems in cities will become an even more serious environmental concern in the next decade in China (Chan & Yao, 2008). The world health organization (WHO) reported that around 7 million people died in 2012 as a result of exposure to air pollution and, air pollution caused one-eighth of total global deaths (WHO, 2014). Air quality monitoring studies have shown that the concentrations of pollutants emitted directly by motor vehicles near large roadways are much higher compared to overall urban background concentrations (e.g., Zhu et al 2002; Harrison et al. 2003; Reponen et al. 2003; Kim et al. 2004; Baldauf et al. 2008a). These higher amounts of concentrations generally occur within a few hundred meters of the road and may vary depending on the traffic patterns, environmental conditions, topography, and the presence of roadside structures (Baldauf et al., 2009). Similarly, factories emissions contribute significantly to the deterioration of air quality in cities which can affect public health (Cirera et al., 2008).

2.2 Urban Built Environment and Health Consequences

Research-based evidence supports the correlation between human health and the built environment (Koohsari et al., 2013). If we can determine the indicators which could be used for assessing the quality of urban built environment in terms of health and well-being, that would help achieve a wide range of policy outcomes. Among many aspects of the urban built environment, inadequate provision of open spaces has been linked to conditions such as obesity, and cardiovascular and respiratory diseases (Lachowycz & Jones, 2011; Pereira et al., 2012; Maas et al., 2009). Open space (OS) is undeveloped land or water body which can be either private or publicly owned and includes areas such as forests, agricultural field, public parks and preserves, and coastal lands (Open Space, n.d.). OS has been recognized as an important component in mitigating health consequences from extreme temperatures, which could result from either urban heat island effect or climate change (Aniello et al., 1995; Jonsson, 2004; Tan et al., 2007). Evidence suggests trees in OS can additionally help reduce particulate matter suspended in the air and as such create a cleaner micro-climate (Selmi et al., 2016).

Assessing amount and quality of OS can account for adult human health and wellbeing putting Social Determinants of Health (SDH) in perspective (Villanueva et al., 2015). The built environment in a neighborhood and associated human behavior can have an effect on health and well-being. This understanding of OS can be employed to identify spatial measures of OS that may be associated with immediate behavioral, intermediate, and longer-term positive health and well-being outcomes.

The association between health and well-being outcomes of OS has been widely researched in urban planning and public health (Bedimo-Rung et al., 2005; Giles-Corti, Broomhall, et al., 2005; Koohsari et al., 2013). OS has been associated with increased physical activity (Giles-Corti, Broomhall, et al., 2005). Availability and access to green spaces encourage behavioral traits such as walking for recreation and engaging in other forms of physical activity (Sugiyama et al., 2010). Open space reduce externalities created from traffic congestion and air pollution (Irwin & Bockstael, 2001). OS provides a place for gathering, interacting and socializing (Kazmierczak, 2013; Peters et al., 2010; Wood et al., 2010; Maas et al., 2009). While open spaces in close proximity encourage walking and physical activities, the quality of the spaces and their sizes are other aspects which determine their possible benefits (Giles-Corti, Broomhall, et al., 2005; Sugiyama et al., 2010; Paquet et al., 2013; Schipperijn et al., 2013)

Besides the immediate benefit of OS to human health and social opportunities it also contributes to improve the livability of a region. For a place to be livable it needs to be safe, attractive, environmentally sustainable and socially functional. Livable communities are defined as affordable and diverse housing linked to employment, education opportunities, public open space, local shops, health and community services, and leisure and cultural opportunities with convenient public transport, walking and cycling infrastructure (Lowe et al., 2013).

The fair allocation of OS has been increasingly recognized as an environmental justice issue. OS should be fairly allocated in an urban setting to ensure everyone has access to a place that can provide for different circumstances in which children are born and raised, and where adults work and deal with illness. OS also has broader relevance to regional and national policies, including biodiversity protection (Sadler et al., 2010), environmental sustainability, regeneration (Chiesura, 2004), and water management (Young, 2010).

Very few examples of evidence-based approaches to developing urban design and planning standards for the provision of open spaces are existent (La Rosa, 2014). There is a growing need to test different policy standards and develop metrics that can potentially measure and control the quality of the built environment. OS can potentially be a good indicator to measure progress towards achieving a better built environment and the reduction of social and health inequalities (State Government Victoria, 2014). Traditionally planners have relied on predetermined standards for making provisions of open space in a city. In many developing world cities, these standards are simply derived from British or American standards, often with little rationale for their application (Veal, 2013). British standards for open spaces were determined based demand for sporting activity in Britain in 1925 and do not include standards for informal open space (Veal, 2013).

CHAPTER 3

Data

All the variables and data needed to perform the empirical analysis have been described in this chapter. The first section presents an explanation of the context of this study. The second and third sections provide a source of information. The final section provides a description of all the relevant variables in the study.

3.1 Built Environment Data

This thesis uses the 2017s Geographic Information System (GIS) dataset from the Ministry of Urban Development, Government of Nepal. This data set is maintained by the Department of Urban Development and Building Construction for the purposes of city planning. These geo-referenced data have information about individual houses, building use, roads, open spaces, and other various aspects of the built environment. This Municipal level settlement data derived from these GIS maps reveal the built-up area in the form of building footprints and roads. Open areas were calculated by subtracting the area occupied by roads and buildings to the total area. The number of factories was also determined using GIS maps.

3.2 Chronic Obstructive Pulmonary Disease (COPD) Data

Data on COPD was gathered from Universal College of Medical Sciences located in Ward Number one in Siddharthanagar Municipality, which maintained manually-filed registers of hospital admissions. These registers had information including name, age, gender, address, contact number, initial diagnosis, admission date, and discharge date. Registers, which began filing in 2014, were the earliest that could be found. The data we collected ranges from January 2014 to February 2020.

The local address provided in the hospital register generally mentioned the local area's name (Tol address) which were matched with wards to produce ward level data. For the purpose of this study, data were collected about hospital admissions due to COPD since 2014. The data were digitized in an Excel format and imported in Stata for Econometric Analysis.

3.3 Data Description

Dependent variable capturing general health effect is PerCOPD. The ratio of hospital admissions to the total population multiplied by 10000 gives us PerCOPD. COPD is an acute lung condition which aggravates due to the increased amount of pollutants in air so it is a good indicator of environmental degredation.

The primary independent variable of interest is OpenArea and NoFactores. Open area was calculated by subtracting the built area and area of roads from the ward's total area. The unit of open areas is expressed in terms of square meters. These existing open area are primarily private land holdings with very small amount of them officially designated as public open spaces. The factories in the area are mostly Rice Mills and other small scale industries which are built within residential settlement. So, their emissions can contribute to increasing particulate pollution of a locality.

Table 1: Description of variables used in this analysis

VARIABLES	Definition	Mean/SD	Min/Max
BldgsArea	Area of buildings by Ward	98,794/62,763	23,928/247,733
NoFactory	Number of factories by Ward	7.923/10.63	0/32
TotPop	Population by Ward	8,351/3,987	3,257/16,197
Area	Total Area by Ward in Sq. m.	2.797e+06/2.045e+06	156,105/6.300e+06
RoadArea	Area of Roads by Ward in Sq. m.	165,932/101,556	31,789/377,600
OpenArea	Open Spaces' area by Ward in Sq. m. (Area-BldgsArea-RoadArea)	2.533e+06/2.043e+06	90,079/5.992e+06
COPD	Total COPD cases by Ward	10.85/8.543	2/26
PerOpenArea	Ratio of Open Space to Total Area by Ward (=OpenArea/Area)	0.794/0.218	0.217/0.985
PerCOPD	Per 10,000 COPD hospital admissions (=NoCOPD/TotPop *10,000)	12.57/7.160	3.561/27.70

CHAPTER 4

Empirical Methods and Models

This chapter explains the econometric method that has been used to determine the relation between open spaces (OS) and COPD outcomes. The method analyzes if the hospitalized cases of COPD can be associated with the amount of open spaces and whether this relation is significant.

4.1 GIS Map and Spatial Correlation

Traditionally planners and geographers rely on various mapping techniques to study the different aspects of built environment. GIS technology has made it possible for gathering, managing and analyzing geographically referenced data. The GIS mapping enables layers of information to be effectively visualized. GIS mapping allows deeper insights into data allowing planners to make smart decision. Planners refer to the GIS maps to inspection of different attributes of built environment graphically. Our investigation thus begins with mapping different aspects of built environment and COPD cases. Spatial spillover effect can be tested in raw data using Moran's I test.

4.2 Estimation Methods

We use regression methods to test the relation between independent variables and the dependent variable. We use linear regression method to test the hypothesis about the impact of independent variables such as open space and factory location and its impact on the dependent variable COPD hospital admissions. We use regular OLS testing, regressing various aspect of the built environment with the health consequence, PerCOPD in this case. The OLS test shows the significance of each variable in contributing to the health consequence. However, the tested variables may have spatial autocorrelation. The spatial examination with spatial correlation test can reveal if there are any significant spatial autocorrelations. Moran's I test of the OLS residuals confirms presence of any such autocorrelation. In case when any spatial autocorrelation is detected there needs to be other spatial regressions which need to be carried out.

Spatial regression begins with the construction of weight matrices. Matrices are created based on the distance between centroids of each area, such defined matrices are assigned as weights. Weights can be binary i.e., assigned 0 or 1, 0 if distance between neighbors is insignificant and 1 if significant. Similarly, weights can also be assigned as decimal points i.e., a neighbor who is assigned as .5 is closer and neighbor assigned .1 is farther away. Two different types of spatial models, Spatial Lag (SL) and Spatial Error (SE) models are then regressed to predict the spatial autocorrelations

4.3 The Empirical Specification

Linear model

According to the literature consulted, this study assumes that there is an association between open spaces to hospital admissions due to COPD. To test if this hypothesis holds true in Siddharthanagar, and to quantify the effect, we used a linear regression model.

$$PerCOPD_i = \beta_0 + \beta_1 PerOpensArea + \beta_2 NoFactory + \varepsilon_i$$

This is an Ordinary Least Squares (OLS) model where *COPD* is the health outcome for the individual ward, *i*. The primary independent variable of interest in our case is the ratio of *open space*. The dependent variable that captures the effect on health is the per 10,000 of total hospital admissions due to *COPD*. Factory emissions contribute to air pollution and as such affect *COPD* cases, we have factored in this through the use of *NoFactory*. ε is the robust standard error in this model.

4.4 Spatial Models

We additionally set up an analysis to see how open spaces could be associated with COPD in spatial terms. To identify spatial variations in relationships, a spatially weighted regression is used in this study. This model reaches beyond the traditional regression framework by allowing spatial properties to be accounted for.

The study uses two types of matrix, inverse distance-weight matrix and binary-weight matrix to regress spatial error (SE) and spatial lag models (SL). Nonnegative matrix, W= (w_{ij}: i,j = 1,..13,) is a spatial weight matrix that displays spatial relations between 13 wards. Here each spatial weight, w_{ij}, typically reflects the "spatial influence" of ward j on unit i . The influence of individual wards on itself is excluded by assuming that w_{ij} = 0 for all i =1,..,13. The Neighbor weight binary matrix is based on the distance cutoff of the 2.5 kilometers. And, Inverse distance weighting is based on the distance of ward i to all other wards it uses.

Spatial Lag Model

This model captures and substantiates spatial dependencies like external effects or spatial interactions. It is based on the assumption that spatial dependencies are seen in the spatial lag Wy of the dependent variable Y. *PerCOPD* is lagged in this model to see if *PerCOPD* has been influenced by neighboring wards.

Spatial Lag Model is specified as:

$$PerCOPD_i = \rho w_{ij} PerCOPD_j + \beta_1 OpenArea + \beta_2 NoFactory + \varepsilon_i$$

Spatial Error Model

The spatial error model is used when spatial autocorrelation occurs as nuisance resulting from misspecification or inadequate delineation of spatial units. The interactions which are not modelled that exist among regions are restricted to the error terms with the use of spatial error model.

Spatial Error Model is specified as:

$$PerCOPD_i = \beta_0 + \beta_1 OpenArea + \beta_2 NoFactory + \varepsilon_i$$

$$\varepsilon_i = \lambda w_i \varepsilon_i + \xi$$

Where, ξ is a white noise.

CHAPTER 5

Empirical Results

5.1 GIS Maps

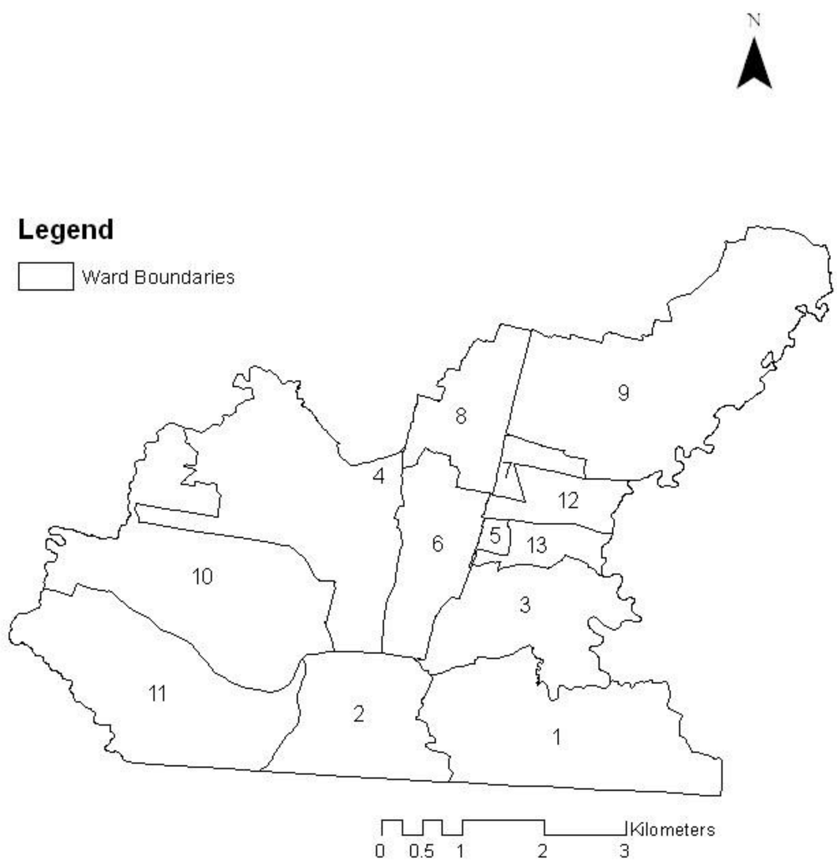

Figure 1: 13 Wards of Siddharthanagar Municipality

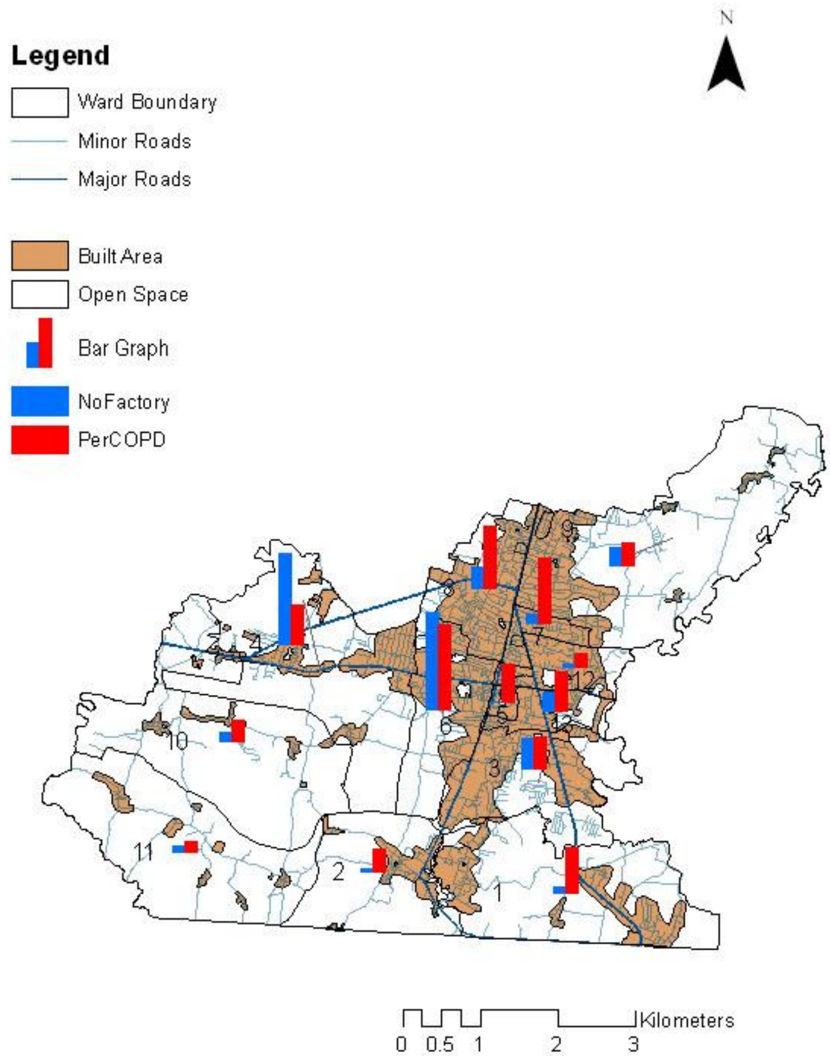

Figure 2: The distribution of built-up area, open areas, roads and bar graph comparing PerCOPD with NoFactory

In the figures above, the GIS mapping allows us to visualize of the structure of settlement, and the distribution of *NoFactories* and *PerCOPD*. We can roughly figure out a pattern through these maps that *PerCOPD* is higher in areas with larger number of factories and lower amount of open spaces. These maps provide insight in spatial terms allowing better understanding of the context.

Table 2: Moran’s I Results on Raw Data

Distance by a simplified version of Vincenty formula (unit: km)

	Obs.	Mean	S.D.	Min.	Max.
Distance	78	2.920	1.488	0.157	7.251
Distance threshold (unit: km):	3				

Moran's I Statistic   Number of Obs   =   13

Variable	Moran's I	E(I)	SE(I)	Z(I)
PerCOPD	0.11280	-0.08333	0.15249	1.28622

We tested for any spillover effect in the raw data and found that the z value being less than 1.65 is insignificant, informing us this effect is insignificant and there is no autocorrelation in the raw data. This measure gives a good understanding of the context. However, linkages and impact can be better understood with specific regressions.

5.2 Linear Regressions

Upon regressing the linear model, we find that the increase in the *NoFactory* and *OpenArea* is significantly associated with the increase in the *PerCOPD.*

Table 3: Parameter estimation results using OLS estimator

	(1) PerCOPD
POpenArea	-20.16***
	(3.509)
NoFactory	0.449**
	(0.183)
_cons	25.02***
	(2.487)
N	13
R^2	0.656

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 shows the inverse relationship between *POpenArea* and *PerCOPD*, suggesting increase in 1 unit of *POpenArea* decreases *PerCOPD* by 20.16. *NoFactories* contribute to *PerCOPD*, increase in 1 unit of *NoFactory* contributing to increase .449 *PerCOPD*. The two independent variables effectively capture and explain the *PerCOPD*.

Moran's I Statistics to test Spatial Residual Correlation

We further tested for the existence of any spatial correlation on OLS residual using Moran's I test, and found it was insignificant and the linear regressive model that was used was able to accurately predict results.

Table 4: Moran’s I Results

Distance by a simplified version of Vincenty formula (unit: km)

	Obs.	Mean	S.D.	Min.	Max.
Distance	78	2.920	1.488	0.157	7.251
Distance threshold (unit: km):	3				

Moran's I Statistic Number of Obs = 13

Variable	Moran's I	E(I)	SE(I)	Z(I)
PerCOPD	-0.21640	-0.08333	0.15265	-0.87169

The Moran’s I statistics shows that the z score, the critical z statistics at 95 percent is 1.65. The z value found here is less than 1.65 and thus insignificant. This implies that the residuals are white noise. We do not find any spatial autocorrelation. This result informs that the OLS regression predicted good results.

5.3 Spatial Regression

As a robustness check we estimate through the use of spatial models. We estimate regression models with two types of spatial effect. First with spatial lag autoregressive model and second with spatial error model. The results of both of these models are presented in Table 5. The results obtained from spatial regression of distance weighted and binary-weighted matrix consistently show that open spaces have a significant role in reducing the hospital admitted cases of COPD.

Table 5: Spatial Regression Results (Dependent Variable: PerCOPD)

Independent Variables	(1) Spatial Error Model - Distance Weight	(2) Spatial Lag Model - Distance Weight	(3) Spatial Error Model - Binary Weight	(4) Spatial Lag Model - Binary Weight
NoFactory	0.444***	0.438***	0.438***	0.454***
	(0.114)	(0.110)	(0.120)	(0.120)
PerOpenArea	-20.26***	-20.27***	-19.04***	-20.77***
	(4.586)	(5.309)	(7.086)	(7.424)
_cons	25.00***	30.71***	23.61***	25.82***
	(3.474)	(9.220)	(7.222)	(7.894)
lambda				
_cons	-0.769		0.00599	
	(0.847)		(0.0253)	
sigma				
_cons	3.787***	3.924***	4.027***	4.034***
	(0.781)	(0.776)	(0.790)	(0.791)
rho				
_cons		-0.405		-0.00485
		(0.582)		(0.0396)
N	13	13	13	13

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We find consistent results in running the spatial regressions. There is inverse relationship between POpenArea and PerCOPD, suggesting increase in 1 unit of POpenArea decreases PerCOPD by 20.16. NoFactories contribute to PerCOPD, increase in 1 unit of NoFactory contributing to increase .449 PerCOPD. The rho values do not show any significance suggesting there is no autocorrelation

CHAPTER 6

Discussion, Conclusion and Policy Recommendation

This study primarily investigates the human health impact that can be attributed to the urban built environment. For this analysis, we used the data from Nepal of the rapidly urbanizing city, Siddharthanagar. This study has been conducted in the context of a developing country. Our results show strong association between urban built environment and health outcomes. The lack of open space and factory count contributes to higher hospital-admitted COPD cases in Siddharthanagar Municipality. This result is thoroughly consistent with the literature about built form and open spaces.

Our findings show provision of open spaces can mitigate the impacts of rapid urbanization in Siddharthanagar. Open space can be a good indicator to measure progress towards achieving a better built environment and help reduce social and health inequalities. Provision of open spaces create cleaner micro-climates and thus reduce the exposure to polluted air. Presence of open space in the neighborhood has positive impacts in bringing behavioral change the residents by encouraging them to walk and engage in physical activity. Open spaces also provide place for gathering, interacting and socializing. Open spaces can accommodate walking, cycling, recreational and green infrastructures. Siddharthanagar can benefit from open space for its biodiversity protection, environmental sustainability, regeneration, water management.

Factories produce emissions which pollute the air. The presence of factories within residential settlement in Siddharthanagar is contributing to degrade the urban environment. Policies should be set in place to regulate these factories; emission standards should be put in place to mitigate the effect of factories in this city. Better zoning and land use policies can be formulated to keep dirty industries out of the residential settlement areas which could enhance the air quality and lead to better health outcomes.

Despite our results being consistent with the literature on built environment and health, there is room for improvement in this study, primarily in two areas. First, the data used has limited resolution. Manually maintained records of hospital admissions provided short term data; longer time series data can effectively increase the accuracy of predictions. Air pollution data and temperature data were not available for individual wards which could add to the precision of the empirical model.

This study has many potential policy implications. There is a growing need for cities in the developing world countries to stop following ready-made standards. It is important to develop evidence based metrics that can control the quality of the built environment. Policy makers can make informed decisions through use of statistical and spatial techniques. Cities like Siddharthanagar, which are in the early stages of developing as urban metropolises can possibly benefit from the use of spatial regression models to inform their planning approaches. Rapidly urbanizing cities such as Siddharthanagar provide unique opportunity to implement evidence-based planning techniques which can help build resiliencies to catastrophic environmental or economic events. Negative externalities such as air pollution can be addressed through informed planning of urban growth from its initial stages, and thus allowing a better perspective of economic growth. A more robust and direct approach to public health and the environment is possible through the application of the thus developed tool in urban planning.

APPENDIX

Stata Code

```
clear all

cd "C:\Users\bisha\OneDrive\Documents\Econthesis\econ599\trial\Boundary"


****convert siddharthanagar ward level shape file into stata dta file

shp2dta using "wardpl", database(urban-d) coordinates(urban-c) genid(id) gencentroids(c) replace

use urban-d, clear // master data   //

sort id

spmap using urban-c, id(id)    /* Works plain map just the district boundary */


//merge open space data with shape file data

use "master.dta", clear

* use all-d,

sort WARD

****merge data

merge 1:1 WARD using urban-d

drop _merge

save all-d, replace


//merge all data with latitude longitude coordinates

use "all-d.dta"

merge 1:1 WARD using coordinates

drop _merge

save all-d, replace


* dropping wards

drop if WARD < 1 | WARD > 13 | WARD == .
```

```
* total COPD

egen COPD = rowtotal(COPD2014 COPD2015 COPD2017 COPD2018 COPD2019 COPD2020)


* factory count

replace factory_count = 0 if factory_count == .


* open space area

gen open_area = Area - area_building - totalareaofroads


* generating popen area

gen popen_area=open_area/Area


* generating ptotal COPD cases

gen ptotal_COPD_cases = COPD/total_population * 10000


* checking for corrlation

corr ptotal_COPD_cases  factory_count  popen_area


* summary stantistics

sum ptotal_COPD_cases  factory_count  popen_area


outreg2 using sum8.doc,replace ///

sum(log) keep(total_population Area factory_count area_building totalareaofroads open_area COPD
popen_area ptotal_COPD_cases)

corr ptotal_COPD_cases  popen_area factory_count pagglung_disorder12 paggstrategy_mask
paggpreventive_measure

estpost corr ptotal_COPD_cases  popen_area factory_count pagglung_disorder12 paggstrategy_mask
paggpreventive_measure, matrix listwise

est store c1
```

```
esttab c1 using "corr1.rtf", replace ///
unstack not noobs compress

sort WARD
spmap ptotal_COPD_cases using urban-c, id(WARD)    /* Works plain map just the ward boundary */

* spatial weight matrix
* spatial weight matrix (Distance based)
spatwmat, name(W_Dist) xcoord(x_c) ycoord(y_c) band(0 3783) standardize eigenval(E_Dist)
* spatial binary weight matrix
spatwmat, name(W_Binary) xcoord(x_c) ycoord(y_c) band(0 2500) binary eigenval(E_Binary)

***spatial corelation test on raw COPD data (spill over)
moransi ptotal_COPD_cases, lat(Latitude) lon(Longitude) swm(bin) dist(2.5) dunit(km) approx detail

***OLS regression and clecking for spatial correaltion
reg ptotal_COPD_cases popen_area factory_count, r
est store OLS

esttab OLS using "OLS.rtf", replace  ///
                    star(* 0.1 ** 0.05 *** 0.01) ///
        se obs r2
***spatial corelation test on OLS residual
predict COPD_res, residual
moransi COPD_res,lat(Latitude)lon(Longitude) swm(bin) dist(2.5) dunit(km) approx detail

****USING DIST. WT.
* spatial error model 1
spatreg ptotal_COPD_cases popen_area factory_count, weights(W_Dist) eigenval(E_Dist) model(error)
```

```
est store A

* spatial lag model (najikaiko le affect garcha)

spatreg ptotal_COPD_cases popen_area factory_count, weights(W_Dist) eigenval(E_Dist) model(lag)

est store B


****USING BINARY WT. MATRIX

* spatial error model 3

spatreg ptotal_COPD_cases popen_area factory_count, weights(W_Binary) eigenval(E_Binary)
model(error)

est store C

* spatial lag model 4

spatreg ptotal_COPD_cases popen_area factory_count, weights(W_Binary) eigenval(E_Binary)
model(lag)

est store D

esttab A B C D using "spatial.rtf", replace ///

	star(* 0.1 ** 0.05 *** 0.01) ///

	se obs ///

	mtitle("Spatial Error Model - Distance Weight" "Spatial Lag Model - Distance Weight" "Spatial
Error Model - Binary Weight" "Spatial Lag Model - Binary Weight")
```

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