Decreased Household Travel Time to Road is Associated with Household Use of Improved Sanitation Systems in the Darjeeling Hills, India

Halley Elizabeth Brunsteter

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master in Public Health

University of Washington

2013

Committee:

Stephen Bezruchka

Fredrick Connell

Matthew Dunbar

Program Authorized to Offer Degree:

Public Health, Global Health

Abstract

We sought to better understand the relationship between household-to-road travel time with improved household latrines in villages in the Kalimpong Subdivision of the Darjeeling District.

BACKGROUND The absence of improved sanitation facilities is the sixth leading risk factor for death in children under the age of 5 worldwide (Insitute for Health Metrics and Evaluation 2013). There is little published about the health-supporting infrastructure in the Darjeeling District while its mountainous, isolating terrain makes its 1.6 million people (Census of India 2011) vulnerable to health risks (Huddleston, Ataman and d'Ostiani 2003).

METHODS This was a secondary data analysis of a cross-sectional household survey of Kalimpong Blocks I and II of the Darjeeling District of West Bengal, India. At both the household and the village level we measured the association of perceived travel time from households to a road with the presence of a household improved latrine.

RESULTS After adjusting for a socioeconomic proxy, the person/room index, we found that an increase of one hour in the travel time to road results in a 21% (95% CI: 36%, 7%) increase in the odds of a household having an unimproved sanitation system.

CONCLUSION In this study we found that the nearer a household is to the road, the more likely it is to have an improved toilet. This relationship remains significant when we account for crowding, a socio-economic proxy.

DISCUSSION Although perceived nearness to road is associated with the increased presence of household sanitation systems, the development of roads as an isolated response to sanitation may be problematic. Due to the introduction of new risk exposures that are coupled with the development of roads it may be necessary to develop roads in conjunction with other infrastructures that support healthy behaviors.

Table of Contents

Tables and Figures

List of Acronyms and Abbreviations

ANOVA	Analysis of Variance Model
GEE	Generalized Estimating Equation
GPS	Global Positioning System
MDG	Millennium Development Goals
NGO	Non-Governmental Organization
SES	Socio-Economic Status
STD	Sexual Transmitted Disease
VHW	Village Health Worker
WHO	World Health Organization

Acknowledgements

I would like to thank my thesis committee members, Stephen Bezruchka, Fred Connell and Matt Dunbar for their guidance and outstanding support during my development while I worked on this project.

I am deeply grateful for time shared with the Hayden Hall and ECTA International staff. They developed the original survey, supported me while I first worked in Darjeeling and created this dataset. The original dataset would not have been gathered without the tremendous work of Hayden Hall's village health workers who went from house to house administering the original survey. I am also incredibly indebted to the people of the Darjeeling District with whom I lived and worked. My family, without question, has supported me throughout this project and my development. For all of these things, I will never be able to show my entire gratitude.

Decreased Household Road Proximity is Associated with Household Use of Improved Sanitation Systems in the Darjeeling Hills, India

Background

Limited access to improved sanitation is estimated to be the sixth leading risk factor for the death of children under 5 years globally (Insitute for Health Metrics and Evaluation 2013). By understanding the infrastructural adjustments that can be made to have a positive impact on the use of improved sanitation systems there may be an opportunity to lessen that burden. The World Health Organization (WHO) made sanitation a priority through the Millennium Development Goals (MDGs) by aiming to increase the percent of the world's population with access to sanitation systems from the 1990 level of 76% to 89% by 2015 (World Health Organization 2012). Though it is nearly impossible for the world to reach the MDG goal of improving sanitation, there is a remaining need for communities and governments to drastically increase access to improved sanitation systems particularly among vulnerable populations.

Study after study points to improved sanitation methods as a way to reduce diarrheal disease spread and exposure to toxins (Sasaki, et al. 2008, Drangert and Nawaba 2011, Nawaba, et al. 2006, Shrestha, et al. 1999, Mara, et al. 2010). Despite the United Nations recognized human right to sanitation (United Nations General Assembly 2010) and the long recognized need for improved sanitation, the international development community is just beginning to understand how different cultures view human excrement, its disposal and the acceptance of certain sanitation methods (Nawaba, et al. 2006, Drangert and Nawaba 2011). A better understanding of the influential factors in households' and communities' intrinsic development of improved toilets could help facilitate a sustainable improvement in sanitation usage. We were particularly interested in roads' relationship to sanitation because of the recent proliferation of road development through the Indian Government's Mahatma Gandhi National

Rural Employment Guarantee Act 2005 (Ministry of Rural Development 2010). This development is controversial because of the concerns about the effect of road development on the spread of malaria and sexual transmitted infections, (Arroyo, et al. 2006, Eisenberg, et al. 2006) and increased social inequality within rural communities in neighboring Nepal (Brown 2003, Blaikie, Cameron and Seddon 2005).

India's Darjeeling District's mountainous terrain makes its 1.6 million people (Census of India 2011) particularly vulnerable to health risks (Huddleston, Ataman and d'Ostiani 2003). There are an estimated 127,943 people living within Blocks I and II of the Kalimpong Subdivision of the Darjeeling District of West Bengal (Office of the Registrar General & Census Commissioner, India 2013). The majority of the population is ethnically Nepali and is commonly called Gorkha. This identity comes from a history of displacement and work supporting colonial forces (Dasgupta 1999). Today, as is common in the Darjeeling District, approximately 86% of all people living on mountainous terrain in Asia are rural (Huddleston, Ataman and d'Ostiani 2003). Access to infrastructure is not well studied in these remote mountain villages but is generally believed to be poor (B. B. Devkota 2007, Devkota, Dudycha and Andrey 2012). The Office of the Registrar General and the Census Commissioner report that none of the people living within the Kalimpong-I and -II live in an urban setting. They also report that approximately 41% of the households in the Kalimpong-I and –II subdivision had no latrines in 2001 (Office of the Registrar General & Census Commissioner, India 2013).

In the Kalimpong Subdivision, many people seem to believe that a nearby road is generally good for a village and therefore positive for the households within the village. When discussing roads, people mention that road access makes it easier to sell the crops they grow and access the healthcare system. But despite the seemingly simple relationship between proximity to roads and other living standards, building new roads may have complicated, potentially negative, impacts on surrounding communities including ecological, social and economic impacts (Egan, et al. 2003, Brown 2003, Blaikie, Cameron and Seddon 2005).

Methods

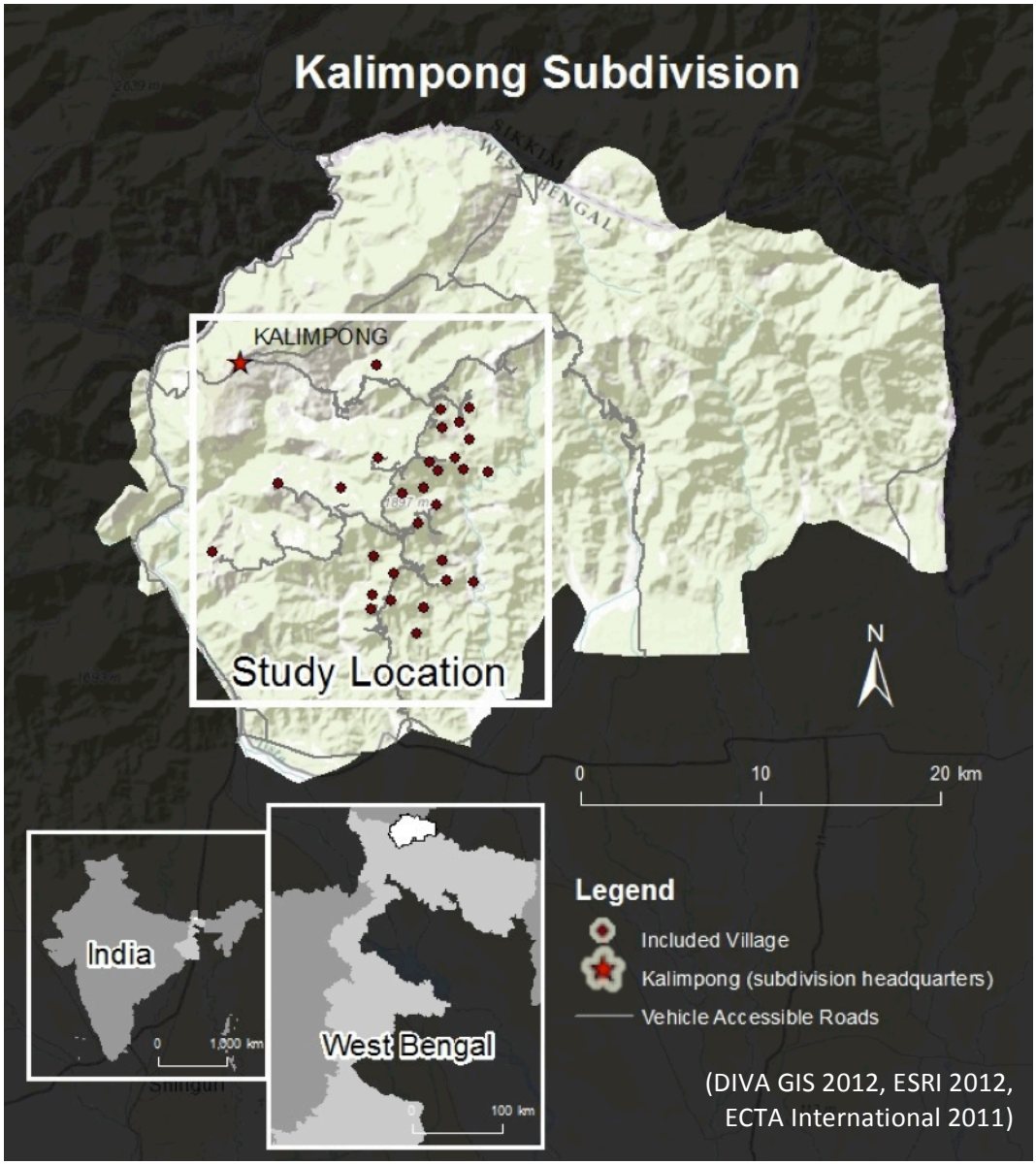
Setting

This was a secondary data analysis of a single cross-sectional survey of the Kalimpong Subdivision's Blocks I and II of the Darjeeling District of West Bengal, India. The data for this study came from a demographic and health survey preformed in 2010. In 1978, the non-governmental organization, Hayden Hall, began training female Village Health Worker (VHW) volunteers selected by their respective communities (Hayden Hall 2008). The village health workers are initially trained during a 6-month first responder and preventative care course at a local hospital. To maintain their skills, the VHWs have annual refresher courses (Kennedy 2010). Beginning in the mid-1980's, Hayden Hall instructed the village health worker volunteers to survey their communities. That data was collected but no information has been extracted from it on a population level (Hayden Hall 2008, Kennedy 2010).

In 2010 Hayden Hall and ECTA International, two non-governmental organizations in collaboration with the Kalimpong Subdivision Health Officer, reformatted the survey to make it more manageable for data entry and analysis. As a part of the annual two-week VHW refresher course, the VHWs tested the survey with one another and modifications to the survey were made. The 30 VHWs were each then given a book of 100 surveys and asked to survey households in their communities. Ultimately, the survey respondents were recruited through a non-random volunteer sampling strategy (O'Leary 2004). The VHWs walked from house to house in their communities asking the heads of the households to complete the survey during a 7-month period. A native Nepali reader read the completed surveys and a single staff member inputted the data into a database. The cross-sectional survey was used to aid Hayden Hall by giving the organization a stronger understanding of the population the VHWs contact (Kennedy 2010).

Figure 1 displays the study's location within the Kalimpong Subdivision of the 28 villages of the total 54 surveyed for which we have GPS coordinates.

Figure 1. Map of the 28 Villages with GPS Coordinates



Organizations

Since 1969, Hayden Hall's services have grown to include afterschool tutoring, educational scholarships, the village health worker training and support, a loan system, weaving classes and

clinics (Hayden Hall 2011). ECTA International is a nonprofit organization that is working to establish improved trainings for Hayden Hall's and other local organizations' VHWs. They aim to connect VHWs to the greater healthcare system including government and private hospitals in the region (ECTA International 2011).

Study subjects/population

All households in the Kalimpong Subdivision of the Darjeeling District of West Bengal survey were eligible to be included in the survey. Using the United Nation's Food and Agriculture Organization's definition, a household is "a group of people who eat from a common pot and share a common stake in perpetuating and improving their socio-economic status from one generation to the next" (Food and Agriculture Organization of the United Nations 2003). Therefore individuals supporting themselves and living alone would be considered a household. One study found that households closer to the road seemed to have smaller amounts of land (Brown 2003) and thus may have more houses grouped closer together. Households that were surveyed in 2010 but were located outside of the geographic area of the Kalimpong Subdivision were excluded from this study.

Analytic Data

The household de-identified data were made public by ECTA International in their initiative to make their work accessible and transparent for anyone who is working in the region (ECTA International 2011). Along with the survey data, ECTA International staff established GPS points for 28 villages in the Subdivision's Blocks I and II, and make that information known publicly through map dispersals throughout the region (ECTA International 2011). These points were established at locations within each village. They were placed at congregating points, in front of a primary school or large areas where community gatherings took place. Because the only identifiable data were the village's GPS coordinates for the villages, this was not considered human subjects research. We then took those GPS points, added them to an ESRI

base map with boundaries from DIVA GIS, and roads provided by ECTA International (ECTA International 2011, ESRI 2012, DIVA GIS 2012). We used the near function in GIS to estimated the distance from the village to the nearest road.

Measures

a. Improved Sanitation System

The primary outcome variable is each independent household's sanitation system. Similar to other rural communities, many families self finance the installment of their toilets (Jenkins and Cairncross 2010). After the survey was administered in 2010, there has been an increased number of household septic tanks after 2011 earthquake relief funds provided for affected families to rebuild their homes with septic tanks. During the survey implementation, the heads of each household reported whether at their household they defecated in the open, had a pit toilet, or had a septic tank. We used the World Health organization's definition of improved sanitation facilities which included piped sewer systems, septic tanks, pit latrines, pour-flush toilets, pit latrines with slabs, composting toilets and ventilated improved pit latrines (World Health Organization, 2006). Figure 2 has images of common improved toilets found in the Kalimpong Subdivision.

Figure 2. Examples of Household Level Improved Toilets

Toilet a. and b. are pit latrines while toilet c. reportedly has a septic tank.

b. Perceived Distance to Roads

We were interested in testing the relationship between distance to road and household latrine adoption. In order to do so, we used the reported travel time to the road as the primary independent variable representing a surrogate for distance to road from each household. One American-based study addressing perceived vs. actual distance to destinations found stronger associations between perceived and actual distances in communities that were more walkable and among people who walked more (McCormack, et al. 2008). For this study based in a predominantly walking-only area, we used the household's perceived travel time to the road in minutes as it was reported on Hayden Hall's original survey. The ambiguity of the village areas could lead to confusion based on the village data point's location and the general inclusion of households in that point (e.g. some general meeting locations may have been at the village's centroid while other meeting locations were on the village's periphery). It is additionally challenging to determine whether the mapped village location's distance is appropriate for all of the households in the village due to the irregular size and shape of each village.

Figure 3. Scatterplot Comparing Perceived vs. Estimated Distance to Road

The scatter plot displayed in Figure 3 shows the relationship between the average household travel time to road and the estimated distance to the road. The r-squared value for this plot is 0.6011. This limited correlation may be due to the aforementioned differences between the two different types of variables. The Darjeeling District's irregular terrain makes the perceived travel time to road further beneficial because the GPS coordinates only account for the two-dimensional distances while the travel time to road potentially includes the variation in terrain. This may however also be related to the average age of household members or other factors that we were not able to control for. In many respects, travel time acts as a way of assessing the cost of travelling in particular locations (Truong and Hensher 1985). Lastly, due to most of the villages being unmapped, with variable place names and the limited resources of data collectors, only 28 of the 54 villages had GPS coordinates and could be included in the mapping portion of the study.

c. Person/Room Index

Parts of Nepal, the ancestral home to the majority of the Darjeeling District's population, are strikingly similar to the hills of Darjeeling. At the household level, the closeness of roads in rural Nepal reflects socioeconomic status (SES); houses closest to the roads tend to be from a higher socioeconomic background than houses further from the road (Jacoby 2000, Brown 2003). Given the strong association of improved sanitation infrastructure and high SES (Rosa and Clasen 2010, Marmot 1994), it was necessary to account for some measure of socio-economic background in the analysis.

The person/room index was developed as a proxy for the household's standard monetary-based SES marker (Galobardes, et al. 2006). The person/room index is calculated by dividing the number of people in a household by the number of rooms. Due to the subsistence farming setting, the person/room index was chosen because households' monetary incomes fluctuate on a seasonal basis and the village setting makes traditional accounting difficulty. Ultimately, the more asset-based approach of the person/room index as an SES proxy can be representative of the families' long-term socio-economic position (Vyas and Kumaranayake 2013).

Analysis

Village Level: Summary Statistics

General summary statistics were generated for the variables: person/room index, improved toilet type, and travel time to road. The means of the villages' person/room index and travel time to road as well as the percent of households with improved toilet types were mapped with the roads and topographic features for the 28 villages with GPS coordinates. The resulting maps can be found in Figures 4a and 4b.

Village Level: Linear Regression

A bivariate linear regression model was used to assess the relationship between each of the 54 villages' mean travel time to the road (independent variable) and the percent of households with improved sanitation (dependent variable). Multivariate linear regression was used to test this same relationship among the 54 villages while adjusting for each village's mean person/room index.

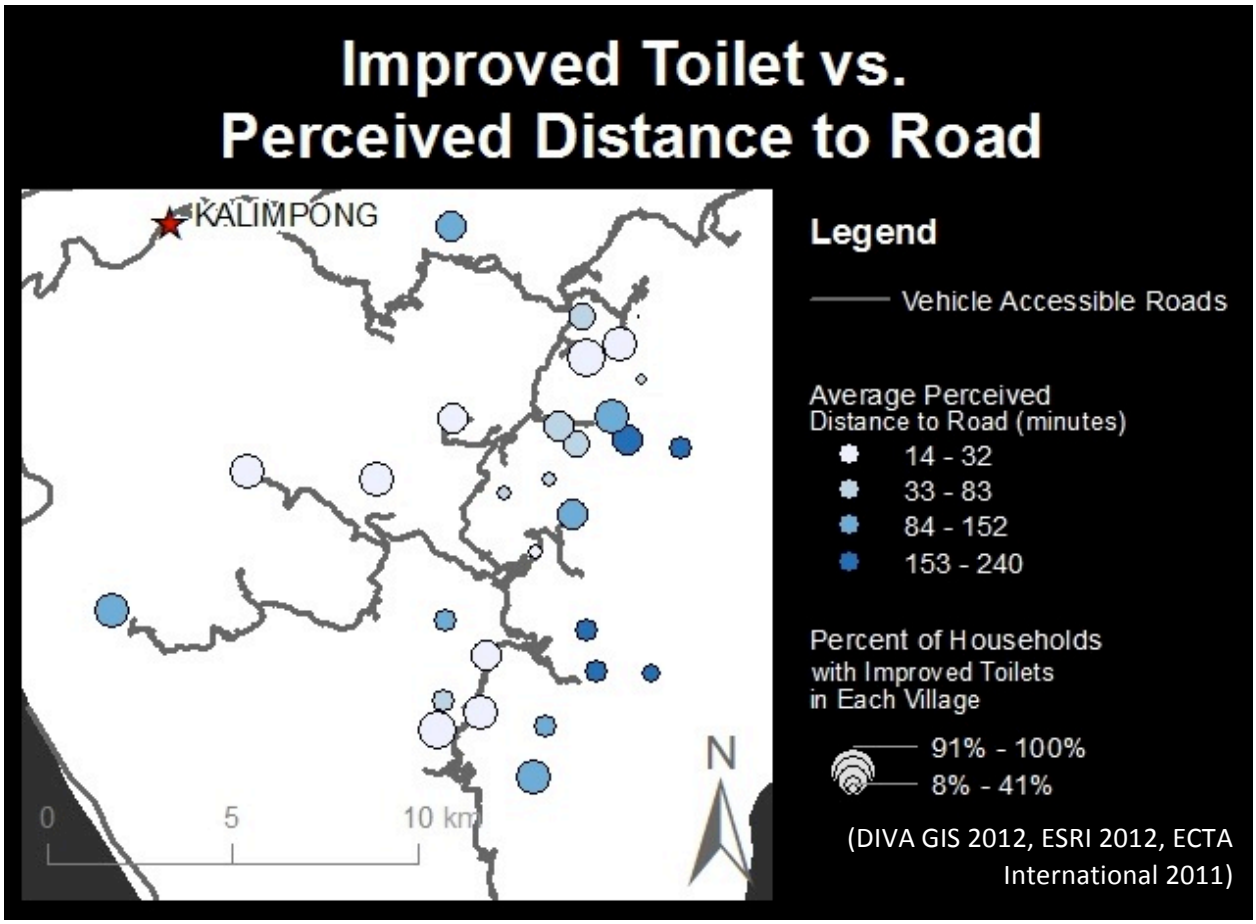
Household Level: Generalized Estimating Equations

A generalized estimating equation (GEE) was used at the household level to assess the association between the dependent variable, presence or absence of improved sanitation systems, and the independent variables, the travel time to roads and the person/room index. The generalized estimating equation accounts for clustering at the village level and thus made the standard errors more robust (Williams 2000). We tested three logistic regression models using the GEE: model a) travel time to road and presence of improved sanitation, model b) person/room index and presence of improved sanitation, and model c) travel time to road, person/room index and presence of improved sanitation.

Results

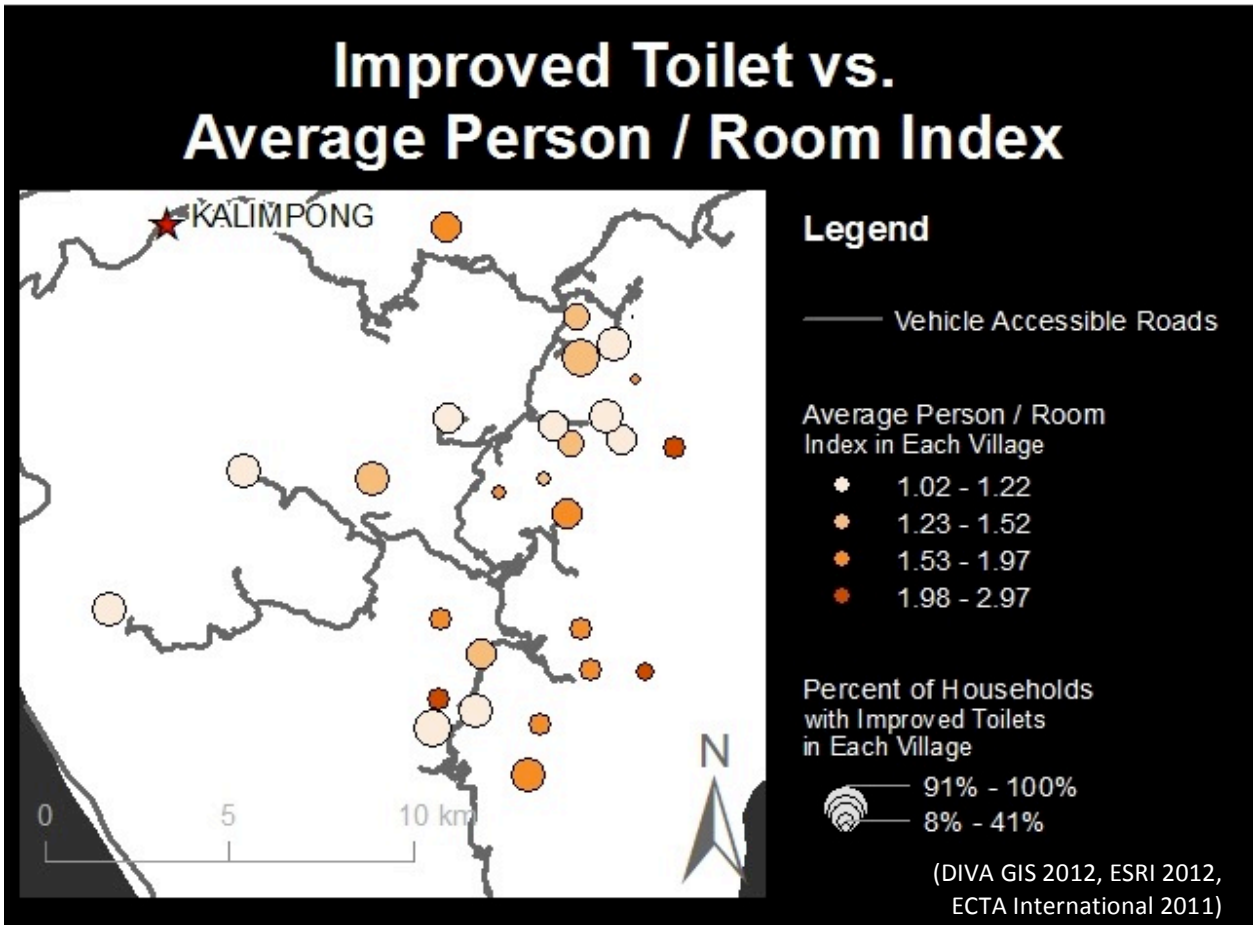
For 28 of the 54 villages, the two-dimensional depiction of the villages' travel time to the road and the prevalence of improved toilets in each village appears in Figure 4a. With this map, it seems that there are more households openly defecating further from the road than are openly defecating in villages closest to the road.

Figure 4a. Map of Improved Toilets vs. Travel Time to Road



The relationship between each village's mean person/room index and the percent of households with improved sanitation systems is found in Figure 4b. For the 28 villages in Figure 4b, there appears to be a relationship between fewer household level toilets and the person/room index. This was confirmed by testing the relationship between the GPS location and the person/room index with a resulting R-squared value of 0.68. In this model, one outlying village was removed.

Figure 4b. Map of Improved Toilets vs. Person/Room Index

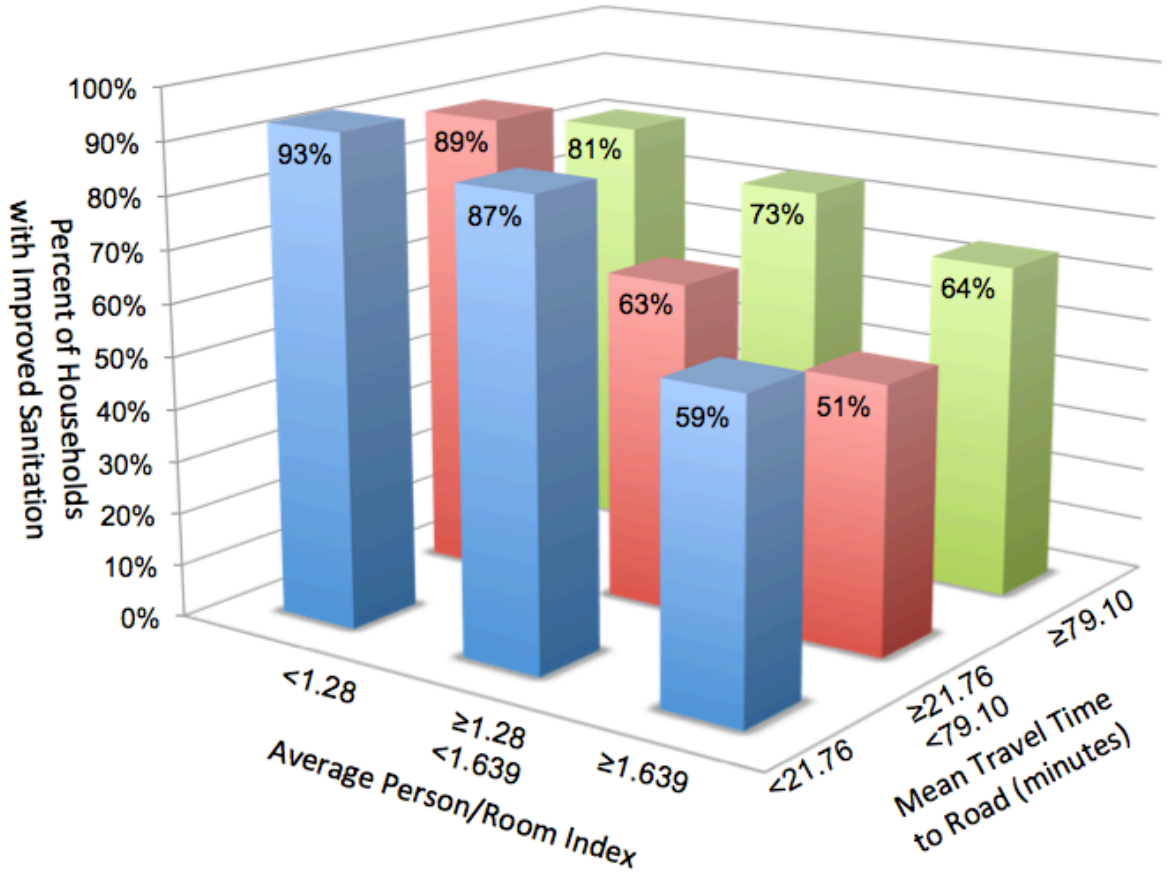


As seen in Table 1, the overall mean of households with improved sanitation systems at both the household level and the village level is 73%. However, the means of the perceived distance to road and the person/room index vary at the village level when compared to that of the household level. This may indicate that due to the variability of the village's size, the village-level data set weighs houses in smaller villages heavier than those in the larger villages.

Table 1. Descriptive Statistics at the Household and Village Level

	n (observations)	Mean	Standard Deviation	Min	Max
Household Level					
Toilet Type *(% with Improved Toilet)*	2294	73%	44%	0%	1%
Travel Time to Road *(minutes)*	2294	55.4	63.7	0	300
Person / Room Index *(# of people / # of rooms)*	1857	1.8	1.0	0.1	10
Village Level					
Household Count	2191 *(in all villages)*	39.8 *(per village)*	31.2 *(per village)*	10 *(per village)*	117 *(per village)*
Toilet Type (*percent of households in village with improved toilets)*	54	73%	22%	8%	100%
Travel Time to Road *(mean reported minutes to the road)*	54	66.0	59.3	8.9	240
Person / Room Index *(mean person / room index)*	54	1.5	0.5	0.9	3.1

Table 2. Average Percent of Improved Toilets (cell values) in Different Tertiles at the Village Level



At the village level we used simple and multivariate linear regression. The bivariate linear regression demonstrated a positive relationship between improved sanitation systems and travel time to roads but this was not statistically significant (p-value= 0.12). Even without adjusting for the distance to road, we observed a significant relationship between person/room index and the percent of households with improved sanitation (p-value=0.004). When comparing two villages with the same average distance to the road but the average person/room index was 1 higher in one village, we observed that the village's percent of households using improved sanitation would likely be 17.1% (95% CI: 31.6%, 6.4%) higher of having unimproved sanitation systems. The relationship between the villages' mean person/room index and the percent of households with an improved sanitation system while

adjusting for the mean distance to road displays the strong correlation between socioeconomic position and improved sanitation system.

At the household level, we used a generalized estimating equation (GEE) in order to account for the clustering of households within each village. Upon adjusting for the person/room index, we found that an increase of one hour in the distance to road would result in a 1.206 (95% CI: 1.363, 1.068) unit increase in the likelihood of a household having an unimproved sanitation system. However, without adjusting for the person/room index, the effect was not statistically significant. All of the aforementioned results are found in Table 3a. and 3b.

Table 3a. Linear Regression at the Village Level

Village Level *(Outcome is percent of households using improved Sanitation)*	Coefficient	95% Conf. Interval	P-Value
Model A: Bivariate Linear Regression			
Mean Hour's Distance to Road	-0.05	(-0.11, 0.01)	0.12
Model B: Bivariate Linear Regression			
Mean Person/Room Index	**-0.19**	**(-0.32, -0.06)**	**0.004**
Model C: Multivariate Linear Regression			
Mean Hour's Distance to Road *(adjusted for Person/Room Index)*	-0.03	(-0.09, 0.03)	0.29
Mean Person/Room Index *(adjusted for distance to road)*	**-0.17**	**(-0.30, -0.04)**	**0.01**

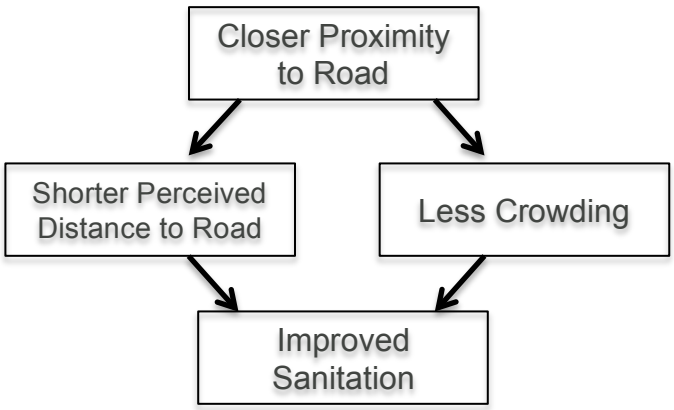
Table 3b. GEE: Logistic Regression at the Household Level

Household Level *(Outcome is the presence or absence of improved sanitation)*	OR	95% Conf. Interval	P-Value
Model A: Bivariate Logistic Regression			
Hour's Distance to Road	0.9	(0.8, 1.0)	0.12
Model B: Bivariate Logistic Regression			
Person/Room Index	**0.7**	**(0.7, 0.8)**	**<0.01**
Model C: Multivariate Logistic Regression			
Hour's Distance to Road *(adjusted for person/room index)*	**0.8**	**(0.7, 0.9)**	**<0.01**
Person / Room Index *(adjusted for distance to road)*	**0.7**	**(0.7, 0.8)**	**<0.01**

Discussion

In this study, we saw that the relationship between socioeconomic position and improved sanitation remained strong when we observed that relationship at both the household and the village level. At the village level, this strength may overshadow the relationship of distance to road and sanitation because the within-village variability of the distance to road is smaller than the person/room index due to the variation in family sizes. In this context, household size is not directly contingent on the location but distance to road is. This relationship can be visualized using Figure 5.

Figure 5. Observed Model



This model is consistent with a study of pit latrine diffusion in Benin and the economic models of rural road development (Jacoby 2000, Jenkins and Cairncross 2010). In Benin, one study found that households nearer to others who had adopted latrines were more likely to have improved toilets than those not near to others with adopted latrines. They also observed associations between the increased use of household latrines and nearness of roads, socio-economic diversity and exposure to education (Jenkins and Cairncross 2010). Their logistic regression found few statistically significant relationships between the presence of a household latrine and other variables. In those models, they did find significant relationships between

improved household latrines and the population size of the village, population density, socio-economic homogeneity, nearby latrine adoption and the presence of a school.

Using ANOVA models the authors also examined the outcome of household latrine development in four different categories: urban fringe villages, agricultural sub-prefecture centres, commune seat villages and small remote villages. Through these ANOVA models, they found that the different groups had statistically significant variations for most of the categories. Significant relationships were seen in the improvement of sanitation systems and nearness to paved roads, fraction of population doing non-agricultural work, an infrastructure index, growth rate, school and piped water (Jenkins and Cairncross 2010).

The variation between the significance found in the ANOVA models and the more limited significance in the logistic regression models may come from the ANOVA's ability to categorize the levels of access into groups rather than trying to isolate effect of the each individual infrastructure.

Despite this present study's observed positive relationship of closeness to roads with an increased household use of improved sanitation systems, the development of roads can be coupled with vulnerability to new unknown exposures. In South America and Africa, studies have found that road development is linked to the spread of infectious diseases including malaria and STDs as well as deforestation (Arroyo, et al. 2006, Eisenberg, et al. 2006, Laurance, Goosem and Laurance 2009, Barcellos, et al. 2010). Road development is also coupled with traffic accidents and higher rates of respiratory illness associated with the greater exposure to air pollution from exhaust (World Health Organization 2004, P English, et al. 1999, Bell and Samet 2010, Hess and Razzak 2010). In other words, the unfettered development of roads as an isolated response to sanitation is likely problematic. Many call for a menu of support including: institutional and community development framework, rural enterprise and agricultural development, primary health care, basic education, and community and institutional development (Barrios 2007, Thaddeus and Maine 1994, Nriagu, Meliker and Johnson 2010).

Through the development of these collective infrastructures, governments and communities can provide its citizens the independence to make informed decisions about investing in items that positively impact their health (Eisenberg, et al. 2012).

Strengths and Limitations

This study provided an opportunity to compare the travel time in minutes to that of a two-dimensional metric point-to-line distance. In so doing the time cost of travel rather than the distance between two points was used as our primary independent variable. The Kalimpong Subdivision has little written about its infrastructure and this type of research may help to inform policy state-funded development projects.

The nonrandom volunteer sampling method of the original VHW survey, the lack of a control group and experimental design of the survey limits the generalizability and inference about the greater population (O'Leary 2004). With relation to the sampling strategy, the village health workers were trained to teach their communities about health promotion. Therefore if the households were surveyed by a VHW they had already been in contact with people supporting the use and development of improved sanitation systems, which may have altered the results to reflect a higher percentage of households with improved toilets.

The definitions of roads and households were also subject to certain biases because the individual respondents determined the definitions for each survey. In general the surveyed household was chosen by the VHWs and therefore the type of household surveyed may differ from one surveyor to the next. We assume that a road is a road motorized vehicles may travel on due to the name in Nepali, Ghadhi ko Bhatto or *path for vehicles*. There are likely cultural issues and physical characteristics of household members not taken into account in relation to the distance to and from roads. Similarly, the presence of a toilet at the household does not necessarily mean that the toilets are the only location for defecation. People may defecate openly while away from the home and without access to a toilet or may not use the household toilet for some other reason.

Due to the small number of villages (54) in the village level regression analysis, limits the statistical power of the analysis. Similarly, there were only GPS coordinates for 28 of the villages and the roads were mapped between 2010 and 2012 with a GPS unit in an ambulance serving the region. The roads were only retrospectively assessed for their presence. Any miscalculations due to poor satellite access could have affected the resulting road maps and the ambiguous nature of road development and blockage due to landslides in the region led to uncertainty about the roads accessibility for vehicles. Due to the imprecise nature of the road mapping, effectiveness in visually displaying the spatial relationships accurately may be limited.

In this study's models, only one confounder was controlled for because of the limited data. The person/room index was used as a socio-economic proxy. At times, the presence or absence of a toilet can also be used as a socioeconomic proxy (Vyas and Kumaranayake 2013, Galobardes, et al. 2006). Therefore the analysis of these two together in place of the household annual earned income is a potential weakness of the study.

Conclusion

In this study we found that the shorter travel time a house has to get to a road, the more likely they are to have a household level improved toilet. This relationship held when we accounted for the socio-economic status of each household by using a crowding index, a socio-economic proxy. As road development is often paired with a whole host of new exposures and risk factors, it may be helpful to develop roads in conjunction with other infrastructures and social support systems encouraging healthy behaviors.

References

Arroyo, Miguel A., et al. "Higher HIV-1 Incidence and Genetic Complexity Along Main Roads in Rakai District, Uganda ." *Epidemiology and Social Science*, 2006: 440-445.

Barcellos, Christovam, Patrícia Feitosa, Giseli N Damacena, and Marco A. Andreazzi. "ighways and outposts: economic development and health threats in the central Brazilian Amazon region." *International Journal of Health Geographies* 9, no. 30 (2010): 1-10.

Barrios, Erniel B. *Dynamics of development in rural communities.* Paper, Tokyo: ADB Institute Discussion Papers,, 2007.

Bell, Michelle L., and Jonathan M. Samet. "Air Pollution." In *Environmental Health From Global to Local Second Edition*, by Howard Frumkin, 387-416. San Francisco: Josey-Bass, 2010.

Blaikie, Piers, John Cameron, and John David Seddon. *Nepal in Crisis.* New Delhi: Androit Publishers, 2005.

Brown, S. "Spatial Analysis of Socioeconomic Issues: Gender and GIS in Nepal." *Mountain Research and Development* 23, no. 4 (2003): 338-344.

Census of India. "Provisional Population Totals Paper 1 of 2011 : West Bengal." *Census of India.* 2011. http://censusindia.gov.in/2011-prov-results/prov_data_products_wb.html (accessed February 1, 2012).

Dasgupta, Atis . "Ethnic Problems and Movements for Autonomy in Darjeeling." *Social Scientist* 27, no. 11-12 (1999): 47-68.

Devkota, Bhuwan Bahadur. *Applications of Geographic Information Systems in planning for pedestrian trail bridges in Nepal.* Masters Thesis, Waterloo: University of Waterloo, 2007.

Devkota, Bhuwan, Douglas Dudycha, and Jean Andrey. "Planning for non-motorized travel in rural Nepal: a role for geographic information systems." *Journal of Transport Geography* 24 (2012): 282-291.

DIVA GIS. *Digital Chart of the World.* January 1, 2012. http://www.diva-gis.org/gdata (accessed 11 20, 2012).

Drangert, Jan-Olof, and Bahadar Nawaba. "A cultural–spatial analysis of excreting, recirculation of human excreta and health—The case of North West Frontier Province, Pakistan." *Health & Place* 17, no. 1 (2011): 57-66.

ECTA International. *Objectives Page.* January 1, 2011. http://www.ecta-international.org/dayasagar-objectives---ecta.html (accessed May 12, 2012).

Egan, Matt, Mark Petticrew, David Ogilvie, and Val Hamilton. "New Roads and Human

Health: A Systematic Review." *American Journal of Public Health* 93, no. 9 (2003): 1463-1471.

Eisenberg, Joseph N. S., et al. "Environmental change and infectious disease: How new roads affect the transmission of diarrheal pathogens in rural Ecuador ." *PNAS*, 2006: 9460–19465.

Eisenberg, Joseph N.S., James Trostle, Reed J.D. Sorensen, and Katherine F. Shields. "Toward a Systems Approach to Enteric Pathogen Transmission: From Individual Independence to Community Interdependence." *Annual Review of Public Health* 33 (2012): 239-257.

Elliott, Paul, and Daniel Wartenberg. "Spatial Epidemiology: Current Approaches and Future Challenges." *Environmental Health Perspectives* 112, no. 9 (2004): 998-1006.

ESRI. *World Imagery.* 11 15, 2012. http://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9 (accessed 11 20, 2012).

Food and Agriculture Organization of the United Nations. *Local institutions and livelihoods: Guidelines for analysis...* United Nations. January 1, 2003. ftp://ftp.fao.org/docrep/fao/006/y5084e/y5084e00.pdf (accessed April 29, 2013).

Galobardes, Bruna, Mary Shaw, Debbie A Lawlor, John W Lynch, and George Davey Smith. "Indicators of socioeconomic position (part 2)." *Journal of Epidemiology Community Health* 60, no. 2 (2006): 95-101.

Goswami, Arjun. *Gorkhaland Movement: A Military Importance.* Kolkata: Knowledge Publishing House, 2010.

Hayden Hall. December 1, 2011. http://www.haydenhall.org/index.html (accessed June 30, 2012).

—. *Paramedic Training.* January 1, 2008. http://www.haydenhall.org/Pages/Paramedic%20Training.htm (accessed April 20, 2012).

Hess, Jeremy J., and Junaid A. Razzak. "Injuries." In *Environmental Health From Global to Local Second Edition*, by Howard Frumkin. San Francisco: Josey-Boss, 2010.

Huddleston, Barbara, Ergin Ataman, and Luca d'Ostiani. *Towards a GIS-based analysis*

of mountain environments and populations. Rome: Food and Agriculture Organization of the United Nations, 2003.

Insitute for Health Metrics and Evaluation. *2010 Global Burden of Disease Study.* January 1, 2013. http://viz.healthmetricsandevaluation.org/gbd-compare/ (accessed April 1, 2013).

Jacoby, Hanan G. "Access to Markets and the Benefits of Rural Roads." *The Economic Journal* 110, no. 465 (2000): 713-737.

Jenkins, Marion W., and Sandy Cairncross. "Modelling latrine diffusion in Benin: towards a community typology of demand for improved sanitation in developing countries." *Journal of Water and Health* 8, no. 1 (2010): 166-183.

Kennedy, John, interview by Halley Brunsteter. "Director, Hayden Hall." *Personal Communication.* (November 1, 2010).

Laurance, William F., Miriam Goosem, and Susan G.W. Laurance. "Impacts of roads and linear clearings on tropical forests." *Trends in Ecology and Evolution* 24, no. 12 (2009): 659-669.

Mara, Duncan, Jon Lane, Beth Scott, and David Trouba. "Sanitation and Health." *PLoS Medicine* 7, no. 11 (2010): e1000363.

Marmot, Michale G. "Social differentials in health within and between populations." *Daedalus* 123, no. 4 (1994): 197.

McCormack, Gavin R., Ester Cerin, Eva Leslie, Lorinne Du Toit, and Neville Owen. "Objective versus perceived walking distances to destinations: correspondence and predictive validity." *Environment and Behavior* 4, no. 3 (2008): 401-425.

Ministry of Rural Development. *Mahatma Gandhi National Rural Employment Guarantee Act .* Report to the People, Department of Rural Development, Government of India, Delhi: Ministry of Rural Development , 2010.

Mondal, Debashri, Subish Barat, and M. K. Mukhopadhyay. "Toxicity of neem pesticides on a fresh water loach, Lepidocephalichthys guntea (Hamilton Buchanan) of Darjeeling district in West Bengal." *Journal of Environmental Biology* 28, no. 1 (2007): 119-122.

Nawaba, Bahadar, Ingrid Nyborga, Kjell Essera, and Petter Jenssenb. "Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan." *Journal of Environmental Psychology* 26, no. 3 (2006): 236-246.

Nriagu, Jerome, Jaymie Meliker, and Markey Johnson. "Developing Nations." In *Environmental Health From Global to Local Second Edition*, by Howard Frumkin, 329-386. San Francisco: Josey-Boss, 2010.

Office of the Registrar General & Census Commissioner, India. *Village Details of Kalimpong Subdivision - II.* March 13, 2013. http://www.devinfo.org/indiacensus2011/libraries/aspx/Catalog.aspx (accessed April 4, 2013).

O'Leary, Zina. *The Essential Guide to Doing Research.* London: SAGE Publications, 2004.

P English, R, R Neutra, M Scalf, L Sullivan, Waller, and Zhu L. "Examining associations between childhood asthma and traffic flow using a geographic information system." *Environmental Health Perspectives* 207, no. 9 (1999): 761-767.

Rosa, Ghislaine, and Thomas Clasen. "Estimating the Scope of Household Water Treatment in Low- and Medium-Income Countries." *The American Journal of Tropical Medicine and Hygiene* 82, no. 2 (2010): 289-300.

Sasaki, Satoshi, Hiroshi Suzuki, Kumiko Igarashi, Bushimbwa Tambatamba, and Philip Mulenga. "Spatial Analysis of Risk Factor of Cholera Outbreak for 2003–2004 in a Peri-urban Area of Lusaka, Zambia." *American Journal of Tropical Medicine and Hygiene* 79, no. 3 (2008): 414-421.

Shrestha, Omkar M., Achyuta Koirala, Jörg Hanisch, Klaus Busch, Martin Kerntke, and Stefan Jäger. "A geo-environmental map for the sustainable development of the Kathmandu Valley, Nepal." *GeoJournal* 49, no. 2 (1999): 165-172.

Thaddeus, Sereen, and Deborah Maine. "Too far to walk: Maternal mortality in context." *Social Science & Medicine* 38, no. 8 (1994): 1091-1110.

Truong, P., and David Hensher. "Measurement of Travel Time Values and Opportunity Cost from a Discrete-Choice Model." *The Economic Journal* (Wiley) 95, no. 378 (1985): 438-

451.

United Nations General Assembly. *64/292. The human right to water and sanitation.* Resolution adopted by the General Assembly, Geneva: United Nations, 2010.

Vyas, Seema, and Lilani Kumaranayake. "Constructing socio-economic status indices: how to use principal components analysis." *Health Policy and Planning* 21, no. 6 (2013): 459-468.

Williams, Rick L. "A note on robust variance estimation for cluster-correlated data." *Biometrics* 56, no. 2 (2000): 645-646.

World Health Organization. *Millenium Development Goals Report.* New York: United Nations, 2010.

World Health Organization. *Millenium Development Goals Report.* Report, Geneva: United Nations, 2012.

World Health Organization. *Road traffic injury prevention.* World Report, Geneva: United Nations, 2004.

—. *Water, Sanitation and Hygiene.* January 1, 2012. http://www.unicef.org/wash/index_statistics.html (accessed June 1, 2012).

World Health Organization,. *Meeting the MDG Drinking Target; Water and Sanitation the Urban and Rural Challenge of the Decade.* Report, Geneva: United Nations, 2006.