RESEARCH

# Topography as a Contextual Variable in Infectious Disease Transmission

ISAAC D MONTOYA

OBJECTIVE: This paper examines whether or not topography is a contextual variable that indirectly influences the transmission of infectious diseases. Age, gender, race/ethnicity, education level, economic status, injection drug use, and high-risk sexual behavior are known to influence infectious diseases transmission, but the effects of topography are often overlooked.

DESIGN: A sample of 395 drug users were chosen from census tracts based upon a target profile of drug use behavior and demographics for the city of Houston. HIV was chosen as the infectious disease used to test this hypothesis.

SETTING: Residents of 16 census tracts in Houston, Texas participated in this study.

RESULTS: The findings revealed that census tracts that were 'isolated' by topographic barriers, such as bayous, parks, railroad tracks, railway yards, major thoroughfares, freeways, and unique street grids had fewer cases of HIV than census tracks that were more accessible to thru-traffic.

CONCLUSION: The research findings suggest that future research studies should consider topography as being contextually related to infectious disease transmission.

ABBREVIATIONS USED: HIV = human immunodeficiency virus

INDEX TERMS: Census tracts; drug user; HIV; infectious diseases; topography.

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*Isaac D Montoya PhD is a Senior Research Scientist at Affiliated Systems Corporation and Professor, College of Pharmacy, University of Houston, Houston Tx.*

*The peer-reviewed Research section seeks to publish reports of original research related to the clinical laboratory or one or more subspecialties. Direct all inquiries to Isaac Montoya PhD, Affiliated Systems Corporation, 3104 Edloe, Suite 330, Houston TX 77027-6022. (713)439-0210, (713)439-1924 (fax). imontoya@affiliatedsystems.com*

*Address for correspondence: Isaac D Montoya PhD, Affiliated Systems Corporation, 3104 Edloe, Suite 330, Houston TX 77027-6022. (713) 439-0210, (713) 439-1924 (fax). imontoya@affiliatedsystems.com*

The purpose of this paper is to present a qualitative case study that examines whether or not topography is a contextual (or control) variable that is related to the transmission of infectious diseases. Control variables such as age, gender, race/ethnicity, education level, and economic status as well as causal variables such as injection drug use and high-risk sexual behavior are known to influence infectious disease transmission, but the effects of topographic barriers, either natural or man-made, are often overlooked.[1-3] The link between topography and infectious disease transmission is indirect in nature, if the link exists at all. Topographic features can indirectly affect infectious disease transmission by serving as barriers to the direct causes of the spread of infectious diseases. For instance, it is plausible to consider that topographic barriers, such as rivers or railway yards, could act to reduce drug trafficking by impeding the ease of access to and exit from areas where drug dealing occurs. The logic follows that with reduced drug trafficking, there would be fewer needles shared among drug users and thus lower incidences of infectious disease. HIV will be used as a proxy for infectious disease transmission. This paper will examine the prevalence of HIV in 16 census tracts in Houston TX to determine if future research studies should include topography as one of the several context-related, control variables that affect HIV transmission.

A careful review of the literature suggests that there is evidence that topographic features play a role in the spread of HIV. One study affirms that HIV transmission is constrained equally by geographic location as well as by the interpersonal ties of social networks.[4] In her study of Uganda, Obbo finds that one region of Uganda had a low prevalence of HIV because it was geographically isolated from other regions with higher incidences of HIV.[4] Potterat demonstrated that the constraints of geographic area may influence, or even determine, behavior patterns associated with the risk of acquiring gonorrhea, and can determine the magnitude of that risk for any given population.[5] And another research study

reports that socioeconomic, cultural, land use, terrain, behavioral, and risk exposure are each factors in the spread of HIV and that they influence each other in complex ways.[6]

Wallace discovered that research on factors that influence the transmission of HIV generally has ignored questions of context, even though any individual who contracts the virus is defined by social, economic, geographic, historical, and other context-related factors.[7] An important consequence of ignoring context-related factors is the finding that HIV transmission has been exacerbated by public policies that allow the degradation and the subsequent desertification of low-income, minority areas.[8-10] These policies have disrupted the socio-geographic-centered networks that confine HIV transmission to tightly clustered 'socio-geographic' spaces.[7] The consequences of such policies have led to more rapid propagation of the disease and to the spread of HIV into the more suburban areas surrounding those that have been 'hollowed out' by poor fire and garbage services.[7,11]

In a study that served as a precursor to this one, Hu and collaborators identified geographic areas, separated by ZIP code boundaries, that were associated with higher incidences of HIV in the Newark, New Jersey metropolitan area.[6] Hu found that in ZIP codes which had the highest prevalence of HIV, there also tended to be the highest percentages of African-Americans who lived in multifamily units. But more interesting to this study, Hu also found that high percentages of HIV coincided with natural topographic features. The Watchung Mountains divide Newark and the Oranges (the cities of Orange, East Orange, South Orange, West Orange, and Maplewood) from other cities in Essex County, and this mountain range may have been a contributing factor to the disparate HIV rates among ZIP codes. Newark and the Oranges have higher incidences of HIV-prevalent ZIP codes than those in the more suburban areas of Essex. Hu and his associates did not consider topography as a context-related variable, and in this case it may have been outweighed by other factors, for there were racial and housing disparities on each side of the mountain range. However, topography would have been clearly influential had the racial composition and percentage of multi-member housing been the same on both sides of the divide.

The Hu study demonstrates that topographic features may have some influence over the prevalence of HIV. However, ZIP codes were designed primarily to facilitate mail delivery to and from respective post offices; they do not necessarily reflect the terrain, zoning provisions, or land use characteristics that may influence behavior.

In this study, census tracts designate geographic areas. In contrast to ZIP codes, census tract boundaries follow visible and permanent or semi-permanent topographic constraints, such as streets, roads, highways, rivers, canals, railroads, high-tension power lines, pipelines, and ridgelines. Census tracts are delineated by local Census Statistical Areas Committees (CSACs) under Census Bureau guidelines, which stipulate that tracts be drawn within county boundaries, have between 2500 and 8000 residents, and be homogeneous with respect to demographic characteristics, economic status, and living conditions when first drawn. Boundaries are delineated with the intent of being maintained for many years so that statistical comparisons can be made from census to census.[12] Given that the most important characteristic of census tract boundaries is that they be readily identifiable from the field, most census tracts are separated by topographic features, making census tracts boundaries ideal for studies involving the effects of topography on human behavior.

Land use issues are particularly salient in Houston TX, because the city does not have zoning restrictions or comprehensive planning. Thus, land use in the nation's fourth-largest city is quite haphazard: a safe, middle-income neighborhood might be surrounded by an industrial park, or an auto garage might coexist in a block of comfortable, turn-of-the-century homes. A map of Houston looks much like a patchwork quilt, because areas reflect the desires of their respective developers. Thus, finding street grids juxtaposed at 90-degree angles to one another is common. Streets that serve as thoroughfares twist, turn, and have changed names three to four times as land was developed, or as the city later connected streets to facilitate traffic flow. Eight freeways cross this quilt of street grids, bayous, and railroad tracks, making Houston a complicated city in which to drive. Stifling heat and humidity, from Houston's proximity to the Gulf of Mexico, make it uncomfortable to travel around town. An inadequate public transportation system makes cross-city travel nearly impossible for those without access to an automobile. Consequently, some areas of town are isolated, and thus confine their residents to staying close to home.

## THE RESEARCH QUESTION

Topography is frequently overlooked as a control variable in research regarding infectious disease (including HIV) transmission among injection drug and crack cocaine users. Topographic features, natural and man-made, could have the effect of facilitating or constraining people's movements and their interactions with their neighbors, including those to whom HIV-infected individuals might transmit the virus.

In cases where topographic features facilitate movement and interactions among people, there may be higher incidences of HIV. But in cases where topographic features constrain movements and interactions, there may be lower incidences of HIV. This case study of census tracts in Houston, Texas is designed to provide an answer to the following question:

Do topographic barriers indirectly influence the prevalence of HIV in and among census tracts?

## METHODS

The study included 395 participants who were classified as out-of-treatment injection drug and crack users and who were also participating as subjects in a five-year research project sponsored by the National Institute on Drug Abuse (NIDA) to evaluate the impact of an intervention designed to reduce HIV transmission. Participants were recruited in person by researchers familiar with areas of Houston where there was high drug trafficking, and participants were asked to refer other drug users to participate by word-of-mouth. The sample was not a random sample but rather one that was targeted to geographic areas delineated by census tract boundaries and that conformed, to the greatest extent possible, to the following target profile within each census tract:

Gender: 70% men and 30% women;
Race: 60% African-American, 20% Hispanic, and 10% white.
Drug-use preference: 70% drug injectors and 30% chronic crack cocaine smokers.

These percentage breakdowns tend to best capture the 'at risk' population of drug users most susceptible to acquiring and spreading HIV, and by holding target profiles nearly constant across census tracts, the 'true' effect of topography can be revealed.[13]

Sixteen 'high-risk' census tracts were included in this study. The criteria used for including a census track was based on arrest records for drug use and reported incidences of diseases.[14] Particularly, the statistical indicators used included arrest rates for drug possession, prostitution, burglary, and incidence rates of syphilis, gonorrhea, tuberculosis, and HIV.

To be eligible to participate in the study, candidates were required to be 18 years of age or older, not to have been enrolled in a drug treatment program for 30 days prior to participating in the study, to have self-reported drug injection within the past 30 days or to have self-reported smoking crack cocaine within 48 hours of the interview. The presence of recent needle track markings and urine drug tests were used to verify injection drug use and cocaine use, respectively. Only those individuals whose drug use was verified participated in this study.

Participants were asked to voluntarily provide blood and urine samples. Prior to having these samples taken, participants were required to sign an informed consent form. The blood samples were tested for HIV using the ELISA assay, which if found to be positive, was then confirmed using the Western blot assay. Participants were paid a nominal gratuity for their participation in the study. All study protocols were approved by an Institutional Review Board.

The data were collected between 1990 and 1995, but despite the data being more than eight years old, much can be learned from this case study that is relevant to research being conducted on infectious disease transmission today. A better understanding of infectious disease transmission is paramount to a bioterrorism prevention/containment program. The study is a snapshot in time, which is designed with the intent of demonstrating whether or not topography is a relevant contextual variable that indirectly influences the spread of HIV. Like with any other variable associated with the spread of HIV, a variable's relevance can change as behaviors and treatments change, but research shows that, with respect to HIV transmission, relevant variables tend to retain their respective effects over time. For instance, even though 'clean needle' intervention efforts tend to reduce the spread of HIV among injection drug users, intravenous drug use is still an influential factor in HIV transmission. If it can be shown that the effects of topography associated with HIV transmission were relevant in 1995, the effects are still likely to be relevant today.

Given Houston's unique landscape, a typology of geographic characteristics is appropriate. The following terms are used to describe land characteristics that may be unfamiliar to those not from the Houston area:

Bayou: A small river or large creek, generally impassable without a bridge.

Freeway: A high-speed divided highway with controlled vehicular access, and on which pedestrians are forbidden. In Houston, the freeways are Interstate Highways 10, 45, and 610; U.S. Highways 59 and 290; and State Highways 8, 288, and 548.

Grid: A road system of uniformly spaced horizontal and vertical streets that facilitate pedestrian and vehicular access.

Natural Barrier: Public or private land in a natural state that is difficult to traverse, e.g., swamp, woodland, pasture.

Rail yard: An industrial center that serves as a hub for multiple railroad tracks with limited or no human access.

Viaduct: A long, elevated roadway that spans a manmade obstacle and is generally longer than a bridge.

Ward: Formerly an administrative and electoral division of Houston; currently refers to an area that roughly corresponds to the original boundaries.

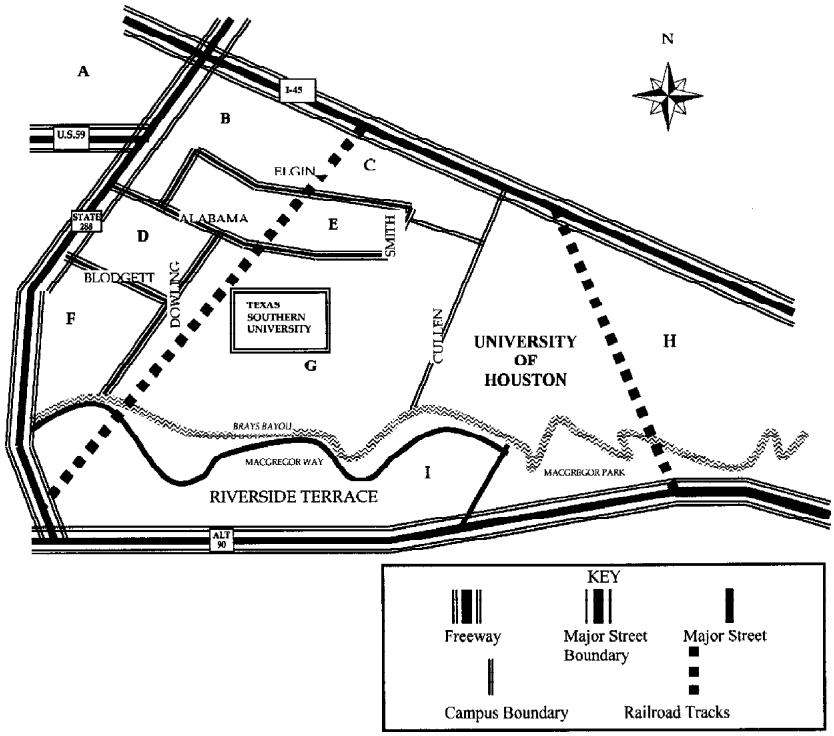
Commercially available maps were purchased to identify topographical features associated with each census tract. The maps provided details on streets, freeways, parks, railroad tracks, railroad yards, and bayous. The maps did not identify fences, viaducts, or walls. The census tracts were inspected by car to verify the information contained on the maps as well as to identify topographic characteristics not shown on the maps but relevant to the study. Census tracts were then coded as 'isolated' or 'non isolated'.

## RESULTS

There is some evidence to suggest that topographic features influence differences in HIV prevalence among census tracts. This study's null hypothesis was that HIV prevalence would be constant across census tracts. However, there was incongruity in the percentages of participants with HIV by census tract. In one example, a major railroad yard separated two low-income minority areas with approximately equal numbers of drug injectors living in each. None of the participants who live north of the rail yard were infected with HIV. In contrast, 25% of participants south of the rail yard were infected with HIV. The key difference between these two census tracts was the presence of the railroad yard.

Evidence also appears to show that HIV transmission is impeded in census tracts that are 'isolated' by topographic features, both natural and man-made. For example, Figure 1 shows the topographic barriers that isolate census tract I (which is also labeled as Riverside Terrace in Figure 1) from the other census tracts. Census tract I is isolated by a bayou, a park, a state highway, a major thoroughfare, and by two railroad tracks. In a sample of 22, there were no cases of HIV in census tract I. In contrast, in census tracts F, G, and H, located across a bayou just to the north of census tract I, the percentages of HIV found were 18% (4 of 22 were HIV+), 11% (2 of 18 were HIV+) and 16% (3 of 19 were HIV+), respectively.

Figure 1: Third Ward and Riverside Terrace




| Code | Census Tract | HIV+/Total N | HIV+% |
|---|---|---|---|
| A | 304.00 | 3/21 | 14 |
| B | 304.01 | 5/26 | 19 |
| C | 304.02 | 4/30 | 13 |
| D | 306.00 | 4/30 | 13 |
| E | 305.01 | 2/36 | 6 |
| F | 307.01 | 4/22 | 18 |
| G | 305.02 | 2/18 | 11 |
| H | 308.00 | 3/19 | 16 |
| I | 315.00 | 0/22 | 0 |

Apart from the topographic barriers that separate census tract I from the other census tracts, there are other distinguishing characteristics. Census tracts F, G, and H are easy to access from the surrounding freeway system, and they have relatively consistent street grids. Six east-west thoroughfares cross the highways and link census tracts F, G, and H to downtown Houston. Also, considered together, four north-south thoroughfares cross the census tracts. Simply stated, census tracts F, G, and H are easy to access, travel through, and exit.

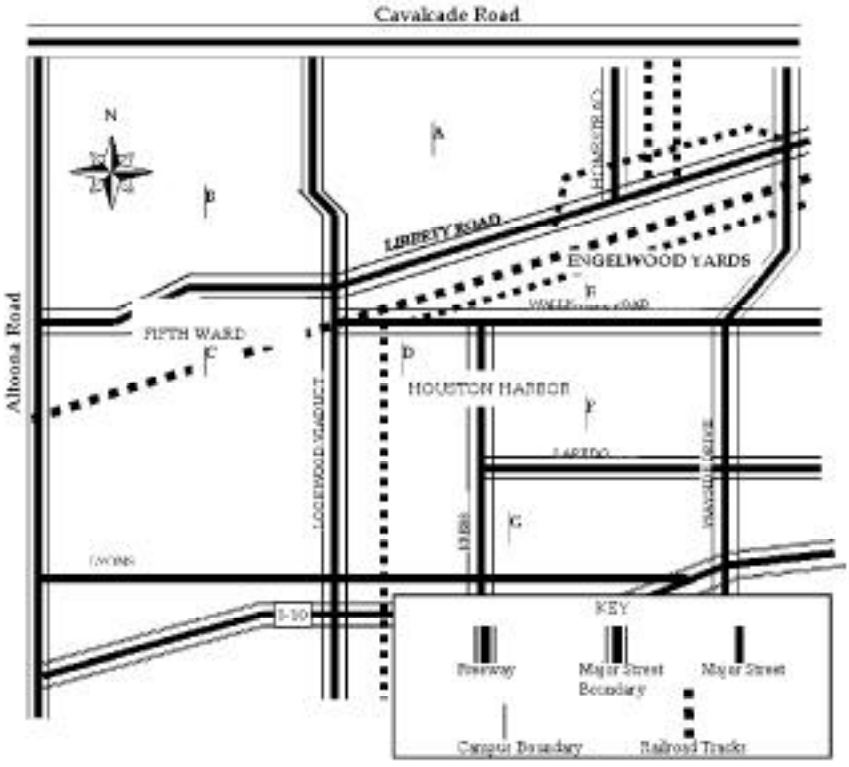
In contrast, census tract I has a broader system of winding streets and has only two north-south thoroughfares that cross it. Census tract I is more residential than the other three; it was designed as a suburb, while the others were designed to be more urban. Census tract I is relatively inaccessible when compared to accessibility to census tracts F, G, and H. The features that isolate census tract I from the others are both topographical barriers and a relatively inaccessible street grid.

Figure 2 shows another case of an isolated area similar to that of census tract I in Riverside Terrace. In this case, census tract D, located in an area named Houston Harbor, is isolated from the others, and in a sample of 17, there were no cases of HIV. The major topographic features isolating census track D are a railroad yard and an interstate highway that border census tract D to the north and south, respectively. A unique street grid isolates census track D from the other census tracts that border it to the east and west. With the exception of one east-west thoroughfare (labeled Lyons Avenue in Figure 2), there are no thru-streets that traverse census tract D. This one east-west thoroughfare is the only easy access to census tract D; all other east-west travel is impeded by census tract D's unique street grid. Northbound traffic across census tract D is discouraged by the presence of the railroad yard, and southbound traffic is channeled down to I-10 on major thoroughfares on the east and west borders of census tract D.

The surrounding census tracts have higher percentages of HIV than census tract D. These percentages range from 9% to 29%. Census tracts A, B, C, E, F, and G, shown in Figure 2, are not 'isolated' like census tract D. They have consistent street grids and have no impediments to east-west or north-south thru traffic.

An anomalous example of an 'isolated' census tract, located in an area known as the Third Ward, also merits discussion. Five census tracts are found within the Third Ward. As Figure 1 shows, four of the census tracts (coded

Figure 2: Houston Harbor and Fifth Ward




| Code | Census Tract | HIV+/Total N | HIV+% |
|---|---|---|---|
| A | 208.02 | 3/29 | 10 |
| B | 208.03 | 7/24 | 29 |
| C | 204.00 | 5/26 | 19 |
| D | 203.01 | 0/17 | 0 |
| E | 203.02 | 3/23 | 13 |
| F | 203.03 | 4/20 | 20 |
| G | 202.00 | 3/32 | 9 |

as B, C, G, and H) surround a central census tract (coded as E). In a sample of 36, only two residents of census tract E were diagnosed with HIV, which is 6% of the sample. Higher percentages of HIV were found in the surrounding census tracts. For instance, 19% of the sample from census tract B, 11% of the sample from census tract G, and 13% of the samples from census tracts C and D, respectively, were HIV positive. What distinguishes census tract E from the surrounding ones is the presence of a low-income housing project and Texas Southern University, a historically African-American public institution. The housing project has a police substation and is heavily patrolled, and the adjoining university has its own police force. As a result, there is no drug trafficking or prostitution in census tract E and in the areas around the university, which is located in census tract G just to the south of the census tract E.

In this case, census tract E is isolated not by topographic features but by a greater police presence and by the presence of a university and a public housing project, which are atypical of the land development found in most census tracts.

## DISCUSSION

The answer to this study's research question appears to be 'yes'. The cases of census tract I in Riverside Terrace and of census tract D in Houston Harbor show that when movement in to and out of a census tract is impeded by topographic barriers and by unique street grids, a lower incidence of HIV is found in the 'isolated' census tract than in those more accessible census tracts that surround it. This 'isolation' effect can also be the result of a greater police presence, but as the case of the Third Ward census tracts show, the existence of atypical land development in the area, namely, a public housing project, and a university, were the reasons for the greater police presence.

One can speculate that the reason for lower incidences of HIV is the result of reduced drug trafficking in 'isolated' areas. It follows that reducing drug trafficking reduces the number of injection drug users and consequently results in fewer cases of HIV. This line of thought begs the question: what causes a reduction in drug trafficking? The cases presented in this study suggest that topographic barriers and specific types of development, such as that which demands a greater police presence, may play roles in reducing drug trafficking.

There are other reasons, of course, that could explain the lower incidences of HIV found in the 'isolated' census tracts and in ones that, because of atypical land development, attract a higher police presence. And these other reasons reveal some of the limitations of this case study. Though it was a goal to stratify the samples across census tracts by race, gender, and by the means in which drugs are consumed, the samples were not randomly drawn nor were they representative, which suggests the possibility of selection bias. Even if proper standards for sampling were met perfectly, the sample sizes were small, opening up the possibility of random error causing the disparities in the incidences of HIV across census tracts. And the number of census tracts analyzed was small in number, again, opening up the possibility of random error. The findings of this study cannot be generalized without corroborating evidence from other research studies on the association of topography and HIV transmission.

Other factors not considered in this study could explain the differences in the incidences of HIV across census tracts. For instance, community leaders in the 'isolated' census tracts may have successfully led efforts to rid the community of drug trafficking. And, people may not live in the census tracts where they buy and use drugs; it is possible for a census tract to have high drug trafficking but at the same time to have a low incidence of HIV because drug users live in other census tracts, though this is not usually the case. Also, census tracts vary in population between 2500 and 8000, and these population disparities could explain differences in the incidence of HIV across census tracts. With all else being equal, it is statistically more likely to find a higher incidence of HIV in a sample of 20 drug users from a population of 2500 than in a sample of 20 from a population of 8000.

Despite this study's limitations, future research may reveal topography as having a contextual association with HIV transmission and other infectious diseases. A conclusive finding as such could have policy implications. In cities where zoning exists, topography could play a role in shaping zoning policies. Cities could, for instance, design zoning ordinances around existing topographic features or mandate that others be built to discourage thru traffic in neighborhood communities, all with the intent of reducing root causes of infectious disease transmission, namely, the injection drug use that is a direct consequent of drug trafficking.

No one questions the influence that injection drug use and high-risk sexual behavior have on HIV transmission, and in virtually all research on HIV transmission, age, gender, education, and race/ethnicity are categorized as control variables to test for the 'true' effects of injection drug use and high-risk sexual behavior. At a minimum, this study shows that the physical context of topographic features may have some

influence on drug use behaviors and consequently have some association with infectious disease transmission. At most, the findings of this study, despite its limitations, suggest that topography also be included in the list of control variables used in future research on infectious disease transmission.

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