Published in final edited form as:

Contemp Nurse. 2018 June ; 54(3): 233–245. doi:10.1080/10376178.2018.1492349.

Beyond bus fare: Deconstructing Prenatal Care Travel among Low-income Urban Mothers through a Mix Methods GIS Study

Joan Rosen Bloch, PhD, CRNP [Associate Professor],

College of Nursing and Health Professions and Public Health, Drexel University, Philadelphia PA

Sarah Cordivano, MUSA [Project Manager],

Data Analytics, Azavea, Philadelphia, PA

Marcia Gardner, PhD, CPNP, CPN [Associate Professor of Nursing and Associate Dean, Undergraduate Programs and Assessment], and

Seton Hall University, South Orange, NJ

Jennifer Barkin, PhD, MS [Assistant Professor]

Mercer University School of Medicine, Macon, GA

Abstract

Background: Lack of access to adequate prenatal health is an important and potentially modifiable risk factor. Transportation (or a lack thereof) is a known barrier to accessing care among low-income women.

Objective: Guided by critical theory, this study illustrates the value of interpretative mapping to deconstruct bus travel to publicly funded prenatal care in a city marked by health and social inequities.

Design: Using geographical information systems (GIS) approach, this mixed methods study delves deeper into the known barrier of transportation to prenatal care among urban mothers most at risk for preterm birth by employing iterative processes among data, analysis, and interpretation.

Methods: GIS maps developed based on **61,305 births** directed neighborhood field excursions for which researchers and key informants created a ‘typical case **vignette**.’ Multiple service locations for required components of prenatal care were geocoded. Time and money spent traveling with public transit were modeled using ArcMap’s Network Analyst.

Results: Among 350 census tracts, 36 census tracts had preterm rates between 25 –36.9%. Modeling travel time for the case vignette for routine prenatal care took 21 visits to different geographically located facilities. This burden increased to 32 visits if the case vignette was high-risk.

Conclusions: Interpretative GIS mapping is an important tool to *ground truth* spatially linked data into real world meaning to promote deeper understandings of complex problems. Time and cost traveling by bus to prenatal care that entailed various locations travel did not account for other

related hassles of getting and waiting for care for mothers with young toddlers in tow. Promoting optimal health outcomes among the most at risk mothers requires innovative and feasible approaches that take into consideration daily maternal functioning as pregnant mothers care for their children and themselves.

Impact Statement—Ground truthing data-driven GIS maps with key informant community-based nurses **is an important method to consider globally** to garner deeper community and family health understandings for future actions.

Keywords

Prenatal care; Underserved populations; Preconception health; Health Disparities; Geographical information systems (GIS); Preterm Birth; Women's Health; Maternal Functioning; Qualitative GIS; Mixed methods

Introduction

Translating health disparities research to practice warrants deeper understandings of point-of-care realities. In addition, innovative methods that promote deeper exploration of the interplay among social problems, health inequities and health are needed, especially to illuminate feasible changes at the practice level (Geronimus, 2013). Despite the availability of large amounts of population health data **throughout the world**, there is a need to make sense of the meaning of data patterns for those receiving care and providing care in communities burdened with poor health. In the population of women at high-risk for preterm birth, a plethora of health disparities research concludes that contextual, upstream factors must be addressed (IOM, 2013; Hogan et al., 2013). Lack of access to adequate prenatal health care is an important and potentially modifiable risk factor (Feijen-de Jong et al, 2013; Kitsantas, Gaffney & Cheema, 2012). Transportation is a known barrier, **globally**, limiting access to adequate prenatal care (Heaman et al., 2015; Makate & Makate, 2017; Webb, Mathew & Culhane, 2014). Building from previous PTB research conducted in Philadelphia (Bloch, 2011; Bloch, Webb., Mathew & Culhane, 2012; Hogan et al., 2013; Webb et al., 2014), we combine large-scale geographical data with a simulated case to illuminate how access to prenatal care for mothers living in areas most at risk for PTB may be challenging because of the urban built environment. Stories and pictures can be powerful and important ways to disseminate knowledge about health issues (Zwald, Jernigan, Payne, & Farris, 2013). So, in this study, we contextualize the pictorial (geographic) data via a story reflecting what travel may entail for a low-income pregnant woman living in a Philadelphia neighborhood that has an extremely high preterm birth rate. In a non-traditional manner, we begin with a story, a hypothetical case-vignette, derived by the method described below, capturing known, modifiable barriers to obtaining adequate prenatal care—childcare and transportation.

Case Vignette

Tara is a 25-year-old **African American** woman at 18 weeks gestation who arrives 30 minutes late to her first prenatal visit at a publicly funded urban health center. She is accompanied by her very active three year old son and her screaming nine-month old infant,

who was born at 27 weeks gestation and still wears an apnea monitor. The receptionist scolds Tara for being more than 15 minutes late and informs her that she must reschedule her appointment. Like most of the mothers in her neighborhood who rely on the public transit system, Tara arrived late due to an unscheduled bus delay. Previously, Tara missed her eight week postpartum family planning appointment because her preterm medically fragile infant was in the emergency room. When she called to reschedule, she was given an appointment at 9 weeks postpartum. Unfortunately, her Medicaid benefits expired at 60 days postpartum and she was now responsible for paying out of pocket for the postpartum visit. Although she knew that she was at risk for another preterm birth and planned to renew the contraception she received when discharged from the hospital, she was unable to afford the cost, did not go to the appointment, and did not continue using the previously prescribed form of contraception.

Background

Preterm Birth

Preterm birth (PTB) is a major public health problem in the United States accounting for more than two-thirds of the racial disparity in infant mortality and subsequent adverse health trajectories across the life course among **African Americans** (Halfon, Larson, Lu, Tullis & Russ, 2014; IOM, 2013). Despite much attention in the literature to racial and ethnic health disparities, they have been persistent for decades (Yudell, 2014). Recently, the Institute of Medicine's 2013 report calls for increased public awareness of the American health disadvantage, in part driven by documented social and health inequities. Americans are at a significant health disadvantage compared to people in all other countries of comparable wealth (IOM, 2013; Avendano & Kawachi, 2014). Mitigating the American health disadvantage requires serious attention to the high PTB rates among **African Americans** (Halfon et al., 2014). Racial and socio-economic segregation in urban neighborhoods is associated with disproportionately higher rates of PTB among **African American** mothers (Kramer, Dunlop & Hogue, 2014).

Challenges for Mothers with Recent Preterm Birth Infants

In the vignette above, Tara missed her postpartum appointment where she planned to renew her contraception, largely because of the competing childcare demands associated with care of her medically fragile infant. As a result, she is now pregnant again and at risk for another preterm birth (PTB). A history of PTB is the most salient predictor of having a subsequent PTB (Hughes et al, 2017). Other research documents that **African American** women have lower rates of contraception use, higher rates of contraceptive failure, and unintended pregnancies than women of other racial/ethnic groups (Bloch et al., 2012; Shah et al., 2011). Preterm infants often require a myriad of healthcare services (Gardner, 2014; Kuo, Lyle, Casey & Stille, 2017); thus, their mothers may be further disadvantaged in receiving timely postpartum care, including medically prescribed method of contraceptive because of competing infant healthcare demands (Hogan et al., 2012).

Known modifiable factors that prevent access to adequate PNC among women are transportation, cost, fragmentation of services, and competing childcare demands (Heaman

et al., 2015). Although transportation is frequently listed as a modifiable factor, the specific aspects of public transportation that prevent access to PNC are largely unknown. Spatial analyses serve to illuminate the built environment and racial/ethnic disparities in PTB by specifically deconstructing the “simple” task of traveling to PNC using public transportation.

Critical Theory: Ground truthing spatial data to seek community practice-based health promotion strategies.

This work is guided by critical theory. Critical theory emerged in the 1920’s as a specific social theory associated with the Frankfurt School (Bonner, 2011; Doucet, Letourneau, & Stoppard, 2010). However, today the term *critical theory* refers to a broader philosophical approach involving critique and reflection of social, political, cultural, economic, ethnic, and gender phenomenon that historically act as a source of oppression (Doucet et al., 2010; Mosqueda-Diaz, Vichea-Barboza, Valenzuela-Suazo & Sanhueza-Alvarado, 2014). Critical theory emphasizes examination of problems from new perspectives; shifting from a traditional positivist epidemiology approach, scholars of multiple disciplines apply critical theory to describe and expose the complexity of life experiences within the intersections of injustice, but with a distinct aim at developing problem-solving strategies for practice (Bonner, 2011; Mosqueda-Diaz et al., 2014).

Promoting optimal population health and disease prevention requires knowing geographical patterns of health and illness along with environmental factors that impact populations. The built environment of where mothers live matters. While this is not a novel idea, we apply a novel approach to illuminate the intersectionality of race, gender, class with health inequities. We present an iterative interpretive process, which we call *ground truthing* that employs geographic information systems (GIS) software (explained below) to critically consider meanings of large amounts of spatially linked individual-level health outcomes data with neighborhood data showing where mothers live and travel to prenatal care. To deconstruct the known barrier of transportation, we *ground truth* perinatal health disparities data to real places of prenatal care. Ground truthing is not a common term in GIS health-related research. However, Bloch & Cordivano (2016) introduce it as a research approach that entails going into the field to the places that the data represent and using GIS-mapped data as a tool to engage community participants for deeper and broader understandings of the health phenomenon under study.

Geographic Information Systems (GIS) Software

GIS computer software is an important tool to better understand the spatial relationships of health and illness. GIS is a computer software system that provides a database for storing, interactively querying, and editing and presenting data in maps. Through the GIS database, large amounts of data from different sources can be integrated together and spatially assigned to investigate geographic relationships. GIS can then be used to present results (e.g., patterns of data) by creating data-driven, visually appealing maps that help tell stories and communicate relationships to illuminate with new insights about the phenomenon under study. Geographic units of analysis can be small such as actual street address based on the longitudinal (X) and latitudinal (Y) coordinates or aggregated to larger geographic units. GIS provides opportunities to connect large amounts of data about people and their local,

regional, national, and global environments. We illustrate the use of GIS in a non-traditional way that began with interpreting multiple GIS created maps, which then led to the creation of a case vignette and more GIS created maps. Through a special add-on network analysis feature in ArcGIS®, travel and cost analyses were conducted. ArcGIS® is a common desktop GIS software. The current study focused on the (a) environment of where mothers live; (b) geographic location of needed healthcare and transportation resources; and (c) schedule of recommended health care visits during pregnancy. Guided by critical theory, the purpose of the study was to use an iterative method of spatial analyses to deconstruct a seemingly simple task of traveling to publicly funded prenatal care using public transit in a city marked by health and social inequities.

METHOD

Research Design.

This was a descriptive GIS sequential mixed-methods study design (Cope & Elwood, 2009; Creswell & Plano Clark, 2017) with three sequential phases. Institutional Review Board approval was obtained prior to the start of the research.

Setting.

Philadelphia is a large city located in the northeastern part of the United States. Approximately 23,000 women who live in Philadelphia give birth annually (Herr & Mallya, 2014). High PTB rates among mothers who live in socioeconomically disadvantaged neighborhoods contribute to the city's documented high infant mortality rates (Herr & Mallya, 2014), which are consistently greater than the national rates (MacDorman, et al., 2014). The infant mortality rate among **African Americans** (14.1%) remains significantly higher than that of Whites (5.4%) and other ethnicities (Herr & Mallya, 2014). An important fact is that locations of reproductive health care services shifted tremendously in Philadelphia between 1997 and 2012 because 13 out of 19 hospital obstetric units closed, resulting in relocation of prenatal and postpartum services, and leaving only six obstetric hospitals (Cordivano, 2011). However, the locations of eight community health centers operated by the Philadelphia Department of Public Health (PDPH) and dispersed throughout the city have not changed in 30 years. Prenatal, postpartum, and family planning services are provided in the PDPH health centers. So, in this study, we strategically use a geographic location of a PDPH health center as the clinic source for prenatal care.

Participants:

The case vignette was developed by researchers and key community stakeholders who interpreted point-of-care meanings for GIS maps of geocoded 61,305 Philadelphia resident births during years 2003–2005. The key community stakeholders (n= 4) were strategically selected because they were community informants with expert knowledge, giving voice to practice-based evidence (Ammerman, Smith & Calancie, 2014). They were invited to participate because they were respected for their experience in caring for pregnant women in Philadelphia at the community health centers, serving this neighborhood and other Philadelphia neighborhoods. The key informants' combined years clinical experience

exceeds over 70 years. Three of the four key informants are life-long residents of Philadelphia.

Quantitative Phase I: Creating the GIS Database

In the first phase of this study, a geographic database of Philadelphia neighborhood characteristics and patterns of PTB was created. Shapefiles and Excel files of existing data were imported into GIS software. The shapefile for Philadelphia is available publicly from Pennsylvania State Spatial Data Access (<http://www.pasda.psu.edu/>) and the US Census Bureau as TIGER/Line® (<http://www.census.gov/geo/www/tiger/>). Census tracts, administrative boundaries designated by the US Census Bureau, were used to simulate the neighborhood spatial boundaries. These contain an average of 4,000 residents (generally between 1,500 to 8,000) and have become the “gold standard” unit of analysis for neighborhood research (Krieger et al., 2003). De-identified aggregated data from resident birth records (2003 –2005), Philadelphia crime statistics (reports of aggravated assaults with guns and domestic violence), and year 2000 U. S. census data (poverty) were imported into the GIS database. Details of this specific GIS database created by Bloch (2011) are published.

Qualitative Phase II: Interpreting GIS maps and creating a “case vignette”

During this phase, inductive reasoning was applied to *ground truth* data visualizations of the data through GIS maps (Bloch & Cordivano, 2016). Creation of the maps was the starting point for organization, analysis and interpretation of the data. The critical question posed by the participants during this phase was ‘what do these maps mean for mothers and clinicians in the context of PTB?’ The question guided analysis of the data and development of the case, described below. During this phase, the perinatal clinical researcher (JB) and the public health spatial analyst (SC) met weekly with excursions into the field to see residential neighborhoods and prenatal service centers, followed by meetings with key informants from the community who provided relevant insights based on their practice-based expertise [36]. Multiple revisions of GIS thematic maps were developed, based on analyses resulting from field trips and meetings with key informants.

To portray possible realities of travel to prenatal care for mothers living in a neighborhood with one of the highest PTB rates, a case vignette with an actual geographic location and related address of an large apartment complex was derived. Travel data is dependent on this address. Using real cases from the existing GIS database would violate confidentiality because resident addresses are identifiers; instead, the phenomenon was modeled through the case vignette. GIS organizes the case vignette data in its environmental context and thus provides a robust way to showcase and visually illustrate the phenomenon and key issues at the patient-experience level.

GIS maps from Phase I were used identify a neighborhood with a particularly high PTB rate. Field trips confirmed a plausible address that would not be an exaggeration, or extreme case, of poverty and travel to care. An apartment building located on the bus route was chosen as the hypothetical residence of the mother. While most of the census tracts with high PTB rates were impoverished, the census tract chosen for the case was not. It was, however,

predominantly African American (racially segregated), had a high PTB rate (Figure 1) and burdened with violence (Bloch, 2011). Key community informants assessed the case vignette's credibility, conformability, and the transferability of GIS data interpretations, in support of quality and rigor of analysis and interpretation of data.

Quantitative Phase III: Calculating time, cost, and distance of travel to PNC Services

This last phase of this study employed ArcGIS to deconstruct the time, cost, and distance of travel to publicly funded prenatal care using public transit based on the address of the case vignette's residence. Reference data using the ArcGIS software extension called Network Analyst was compiled which included all roads and public transit routes for the case studied. Pregnant women who depend on publicly funded health care must use only designated facilities whether or not there are others closer to their residence. For assistance with food and shelter, women rely on public services like the SNAP (Supplemental Nutrition Assistance Program, formerly Federal Food Stamp Program), and WIC (Women Infant and Children Food Subsidy Program). Visits to the prenatal clinic, the hospital's antenatal testing unit (ATU), and public assistance offices were modeled using time, distance, and cost estimations.

The beginning location (home address of the mother) and planned destinations were inputted to calculate the total distance traveled. Next, the cost per trip was computed by the current price of the transit tokens needed to complete a roundtrip journey. Of note, this cost would be higher if the fare is paid by cash instead of tokens. Time was calculated using the Southern Pennsylvania Transportation Authority's (SEPTA) website for the specified route schedules (www.septa.org). Notably, the travel time used in these estimates only includes the amount of time required per route and for walking any remaining distance to the destination. Unpredicted additional time such as required for waiting for a bus that is late, detoured, or experiencing service interruptions is not estimated in this model.

Models for PNC Schedules.

The gold standard schedule for routine PNC visits is based on the American College of Obstetrics and Gynecology recommendations (ACOG, 2012). Care begins early in the first trimester with monthly visits until 28 weeks gestation, biweekly visits until 36 weeks, and weekly visits until delivery. In normal, uncomplicated pregnancies, this entails 13 visits. Advances in technology over time have expanded standards of PNC to include routine ultrasound and genetic screening. For publicly funded care in the neighborhood chosen for this study, PNC visits require regular travel to three different locations: 1) the PNC clinic in the health center for the extensive first office visit, 2) the WIC office for nutritional assessment and counseling, and 3) the obstetric hospital's antepartum testing unit (ATU) for ultrasound and genetic screening. An additional geographic location that a woman must visit is the Philadelphia County's public assistance office for cash, food, and health care assistance for which she would be eligible due to the pregnancy. In this analysis, a conservative number of two visits during the pregnancy was estimated.

For high-risk pregnancies, such as Tara's, additional visits to the PNC clinic and ATU are required. For the purposes of this study, the model was based on biweekly visits to the PNC

clinic that would begin at 20 weeks gestation along with additional visits to the ATU for serial cervical ultrasounds and preventative treatment if indicated (Creasy, Resnick, Iams, Lockwood & Moore, 2014). Weekly injections of progesterone (17-hydroxyprogesterone caproate also referred to as 17P), a preventative treatment against PTB for some women that begins between 16 to 20 weeks and continues weekly to 36 weeks (Cohen & Parry, 2014), was not entered into the model calculation because many mothers receive their weekly injections by home visiting nursing services.

RESULTS

The researchers used the GIS maps, created with large amounts of data, to direct them into the field. A case vignette location where there was apartment complex within a census tract with a high PTB rate as the hypothesized address of the mother in the case vignette. This location was chosen because it houses many people including many single mothers with children, and was right on a large Philadelphia city street, with bus stops right outside, modeling a typical and reasonable scenario. The closest locations of prenatal care services for her in the geographical area are shown in Figure 1. While the residence location is on the edge of the city, it is still very much part of a city neighborhood and serviced with buses that run as frequent as other city buses.

Through GIS, Figure 2 was created in larger scale to better show the actual travel routes for the mother in the case vignette. The actual distances from each location in this geographic area is not very far. First glance at the GIS map may be deceiving; so careful attention to the scale of the map is needed so distances are understood. Each trip consists of a round trip journey from the hypothesized mother's residence to each care facility. All cost, time, and distance calculations were conducted using ArcGIS Network Analyst. A round trip to the designated Public Assistance Office via the H Bus Route takes 58 minutes, is 8.4 miles in distance and costs \$3.60 with bus tokens. A round trip to the designated WIC Office via the H Bus Route takes 18 minutes, is 3.6 miles in distance, and cost \$3.60 with bus tokens. A round trip to the designated Public Health PNC Clinic via the H Bus Route takes 54 minutes, is 8.0 miles in distance, and cost \$3.60 with bus tokens. A round trip to the Obstetric Hospital's Antenatal Testing Unit (via the # 22 Bus Route takes 46 minutes, is 8.0 miles in distance, and cost \$3.60 with bus tokens. Children may accompany their mothers for free if they are less than 60 inches tall. These estimates allowed for a more precise calculation of the time and cost investment required for obtaining the recommended services during a pregnancy. Two scenarios were estimated for a 40 week gestation: 1) a normal uncomplicated, low-risk pregnancy, and 2) a complicated, high risk pregnancy that required more frequent visits.

It was estimated that a woman with an uncomplicated pregnancy served by public funded care should attend 21 appointments. For a woman with a complicated, high risk pregnancy, the estimate increases to 32 appointments. Based on the address of the hypothetical case, if Tara was experiencing an uncomplicated pregnancy and depended on public transportation, she would spend 16.8 cumulative hours on public transportation, travel a distance of 155.6 total miles, and would spend \$75.60 during her 40 week gestation just for bus tokens. However, in this case, Tara is high-risk and needs to attend an additional 11 visits. This

means she would spend 25.5 cumulative hours on public transportation, travel a distance of 243.6 total miles, and spend \$115.20 on public transportation even when using tokens, which is \$0.45 less per trip compared to paying cash for bus fare. For both the low-risk and high-risk scenarios, these findings demonstrate that travel time via public transit is not only lengthy but costly as well. The breakdown of the estimated amount of time, distance and money required to travel to all recommended appointments is provided in Table 1. It should be noted that the calculation only includes travel time, distance and cost for services in a small urban geographical area. They do not include time spent at the specified facilities (“checking in”, waiting, obtaining services, and “checking out”) or the time spent walking to and waiting for transportation. Therefore, these results are underestimates of the total time invested in accessing these specific services. Travel cost would also be higher for individuals relying on public transit who are traveling with children over 60 inches tall (requiring an additional fare) or paying cash instead of using tokens.

Discussion

Building healthy communities requires creative ways to look at complex and persistent problems. Access to prenatal care is important and requires community-level knowledge. GIS is an important tool to use to share research data with key community informants for deeper meanings. This study illustrates methodology to triangulate data through GIS and community-based practice wisdom to promote deeper understandings of the modifiable barrier of transportation to care. Reading data driven GIS maps is important for health promotion practices and policies. Despite the fact that the overall geographic area in which Tara’s residence and services are located is just about five miles (Figure 2), the full travel burden in cost and time is high, and likely is much higher than the time involved in traveling by private vehicle. The number of trips required to different facilities in order to promote a healthy pregnancy is striking. Delving deep to deconstruct the barrier of transportation reveals that just providing bus tokens, which was *not* standard practice when this was written, would not adequately address transportation challenges pregnant mothers may have in accessing adequate prenatal care.

A limitation of the study was that only one simulated case was presented, so it is obviously not representative of travel and costs beyond this one hypothetical case. While the first GIS map that shows preterm rates (Figure 1) *is* representative of > 60,000 births, the travel maps are only representative of mothers that live in the apartment building where the case vignette, Tara, lives. While it would be interesting to show other hypothetical locations, space is limited for additional figures and tables. In the iterative GIS map making process, other neighborhood and locations were simulated. While each location changes the story and pictures slightly, the overall theme is the same. However, our case and related analysis illustrates the utility of this method to examine transportation and other urban-built environment issues.

Another limitation of this study is that the birth data used to create the baseline GIS maps were from 2003–2005 births. It takes several years before surveillance birth data are collected, cleaned, and available to researchers. In this case, the data were geocoded, interpreted, and then displayed visually in maps before even engaging with community-

based stakeholders for practice-based interpretations and further research questions (e.g., transportation barriers). However, despite the lapse in time of the original birth data, the built environment and health disparities in Philadelphia continue to be the same and are documented in the 2017 health report (PDPH, 2017). The health of those living in the most impoverished neighborhoods has not improved. Also, the location of health services and the transit routes have not changed in > 30 years.

Motherhood and Maternal Functioning.

In the case vignette, Tara serves to represent the many pregnant mothers living in socio-economically disadvantaged urban neighborhoods who rely on public transportation to access all necessary services. High-risk mothers with small children, such as Tara, who find themselves pregnant within a short time span may find it tremendously challenging to access PNC services as recommended by clinicians. This may be further complicated if they must also travel with young children and depend on the uncertainties of public transportation. Managing a well or medically fragile infant or an active toddler with an array of paraphernalia, possibly medical equipment, is an arduous task when considering the navigation of bus or subway schedules, costs, and weather.

This study highlights the need to consider the complexity of integrating travel to prenatal and other childcare related appointments via transportation into an already demanding scenario. Mothers are the central ‘case managers’ of many families and function optimally when they are adequately supported, mentally healthy, and possess the ability to: 1) tend to themselves (self-care), 2) take good physical care of their infant, 3) bond with their infant, 4) adjust over time, and 5) manage their various responsibilities (Barkin & Wisner, 2013; Barkin, Bromberger, Beach, Terry & Wisniewski, 2010). Frequent struggles across the course of pregnancy to attend costly appointments with other children and often in inclement weather further complicates the already difficult pathway to good or optimal maternal functioning.

While GIS was used to calculate only travel to prenatal care services, travel to other services that are necessary for all other aspects of daily postpartum functioning were not. Figure 3 provides a conceptualization of possible other services requiring travel. As illustrated in Figure 3, traveling to locations for health care is only one of a complex array of health and social services that a mother is responsible for accessing in order to support her family well-being. These same challenges may exist for women who need to access reproductive healthcare, public assistance, childcare, and healthcare for their children, while using public transportation.

GIS Illuminates Data in New Ways (Impact statement paragraph)

Incorporation of GIS approaches with more traditional health care research can promote better understandings of the social determinants of health (Higgs, 2009). In our study, GIS served as a powerful tool to engage key community clinicians and stakeholders and disseminate health disparities research to them; research rarely trickles down to those busy providing health care in under resourced, low-income clinic settings. In our study, this occurred because of the GIS maps (Ammerman et al., 2014). GIS provided clear

visualization of spatial patterns that would have otherwise been lost. As evident in this analysis, the amount of time and money required to attend all recommended appointments may be so steep that it may force many women to cancel appointments or be unable to show up for necessary care for various reasons.

Scientists are concerned about the challenges in translating life-course health disparities research into practical health promotion interventions (Geronimus, 2013; Nishi et al., 2015). Ground truthing data with community informants that have point-of-care expert knowledge can illuminate possibilities that can make differences to real mothers and their families. Here are some examples of potential changes from small to large. The first is changing clinic policies that prevent patients from being seen if arriving later than 15 minutes of their scheduled appointment. Perhaps, before turning the mother away, a staff member can seriously consider how the clinic is running to see if the mother can be seen. A second larger scale change would be “one stop shopping” for mothers in obtaining prenatal, family, and pediatric care services.

Conclusions.

GIS served as a powerful tool to bring stakeholders together to deconstruct prenatal travel among low-income urban mothers burdened with social and health inequities. Time and cost of traveling to so many locations did not account for other hassles related to waiting for care with children in tow. Acknowledging mothers *are* the case managers of many urban family systems is a step toward tailoring models of *mother-centered* care, accounting for time and cost transportation barriers to all needed services. More efficient and holistic systems of care are needed that place mothers and their family needs at the center of the health care system.

Acknowledgments

Joan R. Bloch obtained IRB approval and National Institute of Nursing Research funding [Grant #: 1K23NR010747] that led to the work reported in this manuscript.

References

- American College of Obstetrics and Gynecology [ACOG] (2012). Guidelines for Prenatal Care (7th edition). Washington, DC: ACOG.
- Ammerman A, Smith TW & Calancie L (2014). Practice-based evidence in public health: improving reach, relevance, and results. *Annual Review of Public Health*, 35, 47–63. doi: 10.1146/annurev-publhealth-032013-182458
- Avendano M & Kawachi I (2014). Why do Americans have shorter life expectancy and worse health than do people in other high-income countries? *Annual Review of Public Health*, 35, 307–25. doi: 10.1146/annurev-publhealth-032013-182411
- Barkin JL & Wisner KL (2013). The role of maternal self-care in new motherhood. *Midwifery*, 2, 1050–5. doi: 10.1016/j.midw.2012.10.001
- Barkin JL, Bromberg JT, Beach SR, Terry MA & Wisniewski SR (2010). Development of the Barkin Index of Maternal Functioning. *Journal of Womens Health*, 19(12), 2239–46. doi: 10.1089/jwh.2009.1893
- Bloch JR (2011). Using geographical information systems to explore disparities in preterm birth rates among foreign-born and U.S.-born African American mothers. *Journal of Obstetric and Gynecologic and Neonatal Nursing*, 40(5), 544–54. doi: 10.1111/j.1552-6909.2011.01273.x

- Bloch JR & Cordivano S (2016). Using Geographic Information Systems (GIS) in nursing research. In Bloch JR, Courtland M, & Clark M (Eds) (2016). *Practice-based PhD-DNP Nursing Clinical Inquiry: Beyond Traditional Nursing Research Methods* New York, N.Y: Springer (in press).
- Bloch JR, Webb DA, Matthew L & Culhane JF (2012). Pregnancy intention and contraceptive use at six months postpartum among women with recent preterm delivery. *Journal of Obstetric and Gynecologic and Neonatal Nursing*, 41(3), 389–97. doi: 10.1111/j.1552-6909.2012.01351.x
- Bronner SE (2011). *Critical theory: A short introduction* New York: Oxford University Press.
- Clemmer G (2010). *The GIS 20: Essential skills* Redlands, CA: ESRI Publisher.
- Cohen AW & Parry S (2014). Compounded 17-hydroxyprogesterone caproate is an inexpensive and safe alternative to the FDA-approved product. *American Journal of Obstetrics and Gynecology*, 210, 12–3. [PubMed: 24359867]
- Cope M & Elwood S (2009). *Qualitative GIS: A mixed methods approach* Thousand Oaks, CA: Sage Publications, Inc.
- Cordivano S (2011). Maternity ward closures in Philadelphia: Using GIS to measure disruption in essential health services. *Journal of Map & Geography Libraries*, 7, 282–303.
- Creasy RK, Resnik R, Iams JD, Lockwood CJ & Moore TR (2014). *Creasy and Resnik's Maternal-Fetal Medicine: Principles and Practice* 7th ed. Philadelphia: Elsevier Saunders.
- Creswell JW & Plano Clark VL (2017). *Designing and conducting mixed methods research* (3rd ed). Thousand Oaks, CA: Sage Publications.
- Doucet SA, Letourneau NL & Stoppard JM (2010). Contemporary paradigms for research related to women's mental health. *Health Care for Women International*, 31(4), 296–312. [PubMed: 20390655]
- Feijen-de Jong EI, Jansen DE, Baarveld F, van der Schans CP, Shellevis FG & Reijneveld SA (2012). Determinants of late and/or inadequate use of prenatal healthcare in high-income countries: a systematic review. *European Journal of Public Health*, 22(6), 904–13. doi: 10.1093/eurpub/ckr164 [PubMed: 22109988]
- Gardner MR (2010). Conceptual, holistic, and pragmatic considerations for interviewing research participants. *Holistic Nursing Practice*, 24(3), 148–57. doi: 10.1111/1552-6909.12508 [PubMed: 20421755]
- Gardner M (2014). Maternal caregiving and strategies used by inexperienced mothers of young infants with complex health conditions. *Journal of Obstetric and Gynecologic and Neonatal Nursing*, 43(6), 813–23.
- Geronimus AT (2013). Deep integration: letting the epigenome out of the bottle without losing sight of the structural origins of population health. *American Journal of Public Health*, 103 (Suppl 1), s56–s63. doi: 10.2105/ajph.2013.301380 [PubMed: 23927509]
- Halfon N, Larson K, Lu M, Tullis E & Russ S (2014). Lifecourse health development: past, present and future. *Maternal and Child Health Journal*, 18(2): 344–65. doi: 10.1007/s10995-013-1346-2 [PubMed: 23975451]
- Herr L & Mallya G (2014). *Vital Statistics Report 2011: Philadelphia* Philadelphia Department of Public Health Philadelphia, PA, retrieved at http://www.phila.gov/health/pdfs/2011VitalsReport_final_51614.pdf
- Higgs G (2009). The role of GIS for health utilization studies: Literature review. *Health Service Outcomes Research Methods*, 9, 84–99.
- Hogan VK, Amamoo MA, Anderson AD, et al. (2012). Barriers to women's participation in inter-conceptional care: a cross-sectional analysis. *BMC Public Health*, 12, 93. doi: 10.1186/1471-2458-12-93 [PubMed: 22296758]
- Hogan VK, Culhane JF, Crews KJ, et al. (2013). The impact of social disadvantage on preconception health, illness, and well-being: an intersectional analysis. *American Journal of Health Promotion*, 27(3 Suppl), eS32–42. doi: 10.4278/ajhp.120117-QUAL-43 [PubMed: 23286654]
- Heaman MI, Sword W, Elliot L, Moffatt M, Helewa ME, Morris H,...Cook C (2015). Barriers and facilitators to use of prenatal care by inner-city women: Perceptions of health care providers. *BMC Pregnancy & Childbirth*, 15 (2), <https://bmcpregnancychildbirth-biomedcentral-com.ezproxy2.library.drexel.edu/articles/10.1186/s12884-015-0431-5>

- Hughes K, Sim S, Roman A, Michalak K, Kane S & Sheehan P (2017). Outcomes and predictive tests from a dedicated specialist clinic for women at high risk of preterm labour: A ten year audit. *The Royal Australian and New Zealand College of Obstetrics and Gynaecologists*, 57, 405–411. doi: 10.1111/ajo.12610
- Institute of Medicine [IOM] (2013). *Health in international perspective: Shorter lives, poorer health*. Washington, DC: National Academies Press.
- Kitsantas P, Gaffney KF & Cheema J (2012). Life stressors and barriers to timely prenatal care for women with high-risk pregnancies residing in rural and nonrural areas. *Womens Health Issues*, 22(5), e455–60. doi: 10.1016/j.whi.2012.06.003 [PubMed: 22841802]
- Kramer MR, Dunlop AL & Hogue CJ (2014). Measuring women's cumulative neighborhood deprivation exposure using longitudinally linked vital records: a method for life course MCH research. *Maternal & Child Health Journal*, 18(2), 478–87. doi: 10.1007/s10995-013-1244-7 [PubMed: 23430295]
- Krieger N (2003). Geocoding and measurement of neighborhood socioeconomic position: A U.S. perspective. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health* Oxford University Press: New York., pp 147–178.
- Kuo DZ, Lyle RE, Casey PH, & Stille CJ (2017). Care system redesign for preterm children after discharge from the NICU. *Pediatrics*, 139 (4), pii: e20162969. doi: 10.1542/peds.2016-2969 [PubMed: 28250024]
- MacDorman MF, Mathews TJ, Mohangoo AD & Zeitlin J (2014). International comparisons of infant mortality and related factors United States and Europe, 2010. U.S. Department of Health and Human Services, Center for Disease Control and Prevention 63 (5), retrieved <http://stacks.cdc.gov/view/cdc/25388/Print>.
- Makate M & Makate C (2017). Prenatal care utilization in Zimbabwe: Examining the role of community-level factors. *Journal of Epidemiology and Global Health*, 7 (4), 255–262. [PubMed: 29110866]
- Mosqueda-Diaz A, Vichea-Barboza V, Valenzuela-Suazo S & Sanhueza-Alvarado O (2014). Critical theory and its contribution to the nursing discipline. *Investigación y Educación en Enfermería*, 32(2): 356–63. Doi: 10.1590/s0120-53072014000200018 [PubMed: 25230045]
- Nishi A, Kawachi I, Koenen KC, Wu K, Nishihara R, & Ogino S (2015). Lifecourse Epidemiology and Molecular Pathological Epidemiology. *American Journal of Preventative Medicine*, 48(1), 116–119. doi: 10.1016/j.amepre.2014.09.031
- Philadelphia Department of Public Health [PDPH] 2017 2017 Health of the City Retrieved http://www.phila.gov/health/pdfs/Health_of_City_report_FINAL_lowres.pdf
- Shah PS, Balkhair T, Ohlsson A, Betene J, Scott F & Frick C (2011). Intention to Become Pregnant and Low Birth Weight and Preterm Birth: A Systematic Review. *Maternal and Child Health Journal*, 15 (2), 205–216. doi: 10.1007/s10995-009-0546-2 [PubMed: 20012348]
- Watson LF, Rayner JA, King J, Jolley D, Forster D & Lumley J (2010). Modelling sequence of prior pregnancies on subsequent risk of very preterm birth. *Paediatric and Perinatal Epidemiology*, 24(5), 416–23. [PubMed: 20670222]
- Webb DA, Mathew L & Culhane JF (2014). Lessons learned from the Philadelphia Collaborative Preterm Prevention Project: the prevalence of risk factors and program participation rates among women in the intervention group. *BMC Pregnancy Childbirth*, 14(1), 368–378. doi: 10.1186/s12884-014-0368-0 [PubMed: 25361563]
- Yudell M (2014). *Race Unmasked: Biology and Race in the twentieth century* New York: Columbia University Press.
- Zwald M, Jernigan L, Payne G & Farris R (2013). Developing stories from the field to highlight policy, systems, and environmental approaches in obesity prevention. *Preventing Chronic Disease*, 10, 120141. doi: 10.5888/pcd10.120141. [PubMed: 23411034]

Figure 1.
GIS Density map of PTBs in Philadelphia with location of 'Case Vignette' residence and PNC services.

Figure 2.
GIS map of actual travel routes by public transit buses to access PNC services.

Mother = Master

To be successful at accessing the entire system, the mother must be a *Brilliant, Exemplary Case Manager*.

Figure 3.
The mother as 'Master' navigator to multiple systems.

Table1.

Two travel scenarios to publicly funded facilities as part of recommended PNC for a *low risk and high-risk* pregnant woman at the specified address of the ‘case vignette.’

	Facility	Number of visits	Time spent traveling (minutes)	Miles traveled	Cost of public transportation* for travel
Low-Risk Pregnancy	Public Assistance Office	2	116	16.8	\$7.20
	WIC Office	3	54	10.8	\$10.80
	Obstetric Hospital's Antenatal Testing Unit (ATU) **	3	138	24	\$10.80
	Publicly funded Health Center	13	702	104	\$46.80
	Totals for low-risk	21 visits	16.8 hours	155.6 miles	\$75.60
High-Risk Pregnancy	Public Assistance Office	2	116	16.8	\$7.20
	WIC Office	3	54	10.8	\$10.80
	Obstetric Hospital's Antenatal Testing Unit (ATU) ***	12	552	96	\$43.20
	Publicly funded Health Center	15	810	120	\$54.00
	Totals for high-risk ****	32 visits	25.5 hours	243.6 miles	\$115.00

* Reduced-price bus token were \$1.80 (or #3.60 for round trip journey) at the time this report was written.

** Routine antenatal testing includes Part 1 and 2 of Sequential screen (Nuchal cord translucency and quad screen) and 20-week anatomy ultrasound

*** Increased number of visits to monitor for signs of prematurity

**** (i.e., ultrasounds assessing cervical length and funneling; clinic visits every 2 weeks). Weekly injections for 17-****Hydroxyprogesterone (17-OHP) were not part of the calculation because there is variation of whether the mother gets it weekly at home by a home visiting nurse or if she has to travel to get it. The travel could be at the ATU or the prenatal clinic.