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SPATIAL VARIATION OF LOW BIRTH WEIGHT AND ITS ASSOCIATION WITH  
SOCIOECONOMIC STATUS, HOUSING TYPES, AND ACCESSIBILITY IN  
KALAMAZOO COUNTY

by

Eugene Kojo Opare Ahwireng

A thesis submitted to the Graduate College  
in partial fulfillment of the requirements  
for the degree of Master of Science  
Geography  
Western Michigan University  
June 2019

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Eugene Kojo Opare Ahwireng

# SPATIAL VARIATION OF LOW BIRTH WEIGHT AND ITS ASSOCIATION WITH SOCIOECONOMIC STATUS, HOUSING TYPES, AND ACCESSIBILITY IN KALAMAZOO COUNTY

Eugene Kojo Opare Ahwireng, M.S.

Western Michigan University, 2019

Infants with low birth weight due to early delivery or fetal growth restriction face an increased risk of health conditions and deaths. These risk factors and the cost associated with healthcare for infants makes low birth weight a major public health problem. Understanding early precursor challenges expectant mothers face before delivery would help in planning interventions to reduce low birth weight among infants.

This study investigated and evaluated the spatial variation of low birth weight incidence with respect to socioeconomic status, housing types and accessibility in Kalamazoo County. In a broader scope, this research study examined the geographic patterns of low birth weight cases and calibrated factors responsible for disparities among different populations considering individual maternal characteristics and block group level characteristics. This research study was conducted at a local scale to plan interventions to reduce disparities in low birth weight in the urban-rural continuum of Kalamazoo County.

The study found that at the individual level, low birth weight was associated with race, age, educational status, and Medicaid insurance of mothers. Young women (less than 20 years), women with less than high school education, blacks, and women with Medicaid insurance are more likely to have infants with low birth weight. At the block group level, there was high incidence of low birth weight rates for block groups with low socioeconomic status and high renter occupied units. Spatial distribution map of low birth weight showed high incidence of low birth weight rates for block groups in rural areas with high population density of whites.

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## CHAPTER I

### INTRODUCTION

The relative health of an infant population is representative of the overall health of a nation and has a great significance on the nation's future especially when infants grow into adults (MacDorman, et al., 2013). Infant mortality is known to be one of the important statistical indicators of a society's health since it reflects the health status and well-being of the entire nation (Singh et al., 2008). According to the Central Intelligence Agency (CIA), even though the US is one of the highest per capita healthcare spenders in the world, it ranks 56<sup>th</sup> out of 224 nations in infant mortality (CIA, 2014). In the US, there are 10 leading causes of infant mortality and over the years, low birth weight has been identified as the second leading cause of infant mortality (Kochanek et al., 2017).

Birth weight of infants is very important because it plays a major role in predicting infant mortality and morbidity, childhood development, and adult health (Sebayang et al., 2012). According to the World Health Organization (WHO), low birth weight is defined as birth weight of infants below 2500 grams (5.5 pounds) and this definition focuses on the epidemiological observation that infants that weigh less than 2500 grams have a higher risk of neonatal mortality as compared to infants with normal birth weight (WHO, 2004). Low birth weight constitutes about 4 million deaths every year and it is a major risk factor for infant mortality and morbidity (Singh et al., 2009). Low birth weight infants, unlike babies with normal weight, do not only have adverse health conditions like neurodevelopmental complications and congenital abnormalities but also are 40 times more likely to die within the first four weeks of birth (Singh et al., 2009).

Low birth weight accounts for about 60-80% of neonatal deaths globally (WHO, 2004). Low birth weight contributes to adverse health outcomes especially in developing countries where there is high rate of infant mortality and morbidity (Sebayang et al., 2012). There is the need to have proper knowledge on risk factors or determinants of low birth weight since this would help to identify and give appropriate care to mothers at risk (Hailu & Kebede, 2018).

In the United States, racial health disparities such as inequalities in birth outcomes is a major problem that affects the entire population (Mathews et al., 2002). Disparities in racial health are highly prevalent and substantial across numerous indicators of health status. In the US, African Americans or blacks have a high death rate for 8 out of the 10-leading causes of deaths (Frederick et al., 2008). Although global population health indicators have improved over the years, racial health disparities in the United States have increased tremendously (Roux, 2012; Orsi et al., 2010). Over the past years, despite increasing access to prenatal care, there still exist a gap in birth outcomes between the white and black race. In the United States, black infants as compared to white infants are more than twice as likely to die (11.6 and 5.2 deaths per 1000 live births respectively) and this gap has remained consistent (Murphy, 2013; Orsi et al., 2010).

There are disparities in health among populations with different levels of socioeconomic status (as typically measured by education, income, and occupation). The gross inequalities in health between different populations constitute some challenges in public health (Marmot, 2005). According to a research study by Mackenbach et al. (2008), there are variations in the magnitude of disparities in health related to difference in socioeconomic status. Results of the research study explains that there is high rate of deaths associated with people of low socioeconomic status as compared to high socioeconomic groups, and as such these disparities might be reduced by

improving access to health care, educational opportunities, income, and health related behavior (Mackenbach et al., 2008).

Socioeconomic status is one of the main sociodemographic factors responsible for disparities in health in a diverse population. Health disparities based on different socioeconomic status or race is commonly found among different populations in the United States. Hence, one of the main objectives of the Healthy People 2000 Program in the US was to eliminate health disparities; a national statement of health objectives (Marwick, 2003). Maternal socioeconomic status varies with respect to race and ethnic subgroups and has been found to be a key risk factor for disparities in birth outcomes. Socioeconomic disparities in birth outcomes are common and are associated with disadvantage measured at the individual and neighborhood levels (Blumenshine et al., 2010). Aside from individual socioeconomic characteristics, neighborhood socioeconomic status could possibly affect an infant's birth weight depending on factors such as maternal ethnicity and nativity (Kothari et al., 2016; Pearl et al., 2001).

According to the US Department of Health and Human Services, the term “healthy housing” is used to describe a housing unit that is designed, sited, built, and renovated to provide good quality health to residents due to frequent and high-quality maintenance (USDHHS, 2009). Conditions in housing units that lead to health inequalities can be grouped into 5 categories which include, physical factors (heat, cold, energy efficiency, radon exposure, noise, inadequate light, ventilation), chemical factors (carbon monoxide, volatile organic chemicals, secondhand smoke, and lead), biological factors (rodents, house dust mites, cockroaches, humidity and mold), social factors (for example, architectural features related to mental health), and building and equipment conditions such as accidents, unintentional injuries, access to sewer services hygiene and sanitation issues (Bonney, 2007). Past research has shown that differences in built environment across a

region may eventually result in neighborhood-level disparities in health, especially infant health (Cummins & Jackson, 2001). Although some believe that the health outcome of a population is dependent on geographic location and sociodemographic status of residents in their respective neighborhoods (Sloggett & Joshi, 1994), other studies have also concluded that there are key features of the local social and physical environment, for example characteristics of the indoor built environment, such as housing type and quality, that could possibly affect (promote or inhibit) health (Bashir, 2002; Macintyre et al., 2002; Northridge, 2003; Vlahov et al., 2007). Irrespective of their geographic location, poor housing quality contributes to poor health outcomes. Previous studies have shown that, people in urban neighborhoods that live in poor-quality houses, have a variety of poor health outcomes (Bashir, 2002; Rauh et al., 2002; Rauh et al., 2008). For example, people who live in older houses associated with peeling paints may have high blood lead levels, especially true for children (Center for Disease Control and Prevention, 2002). Northridge et al. (2010) found a significant association between housing types and childhood asthma. In this research study, children living in public housing had higher odds of childhood asthma as compared to residents of all types of private housing.

Correcting adverse health outcomes due to differences in access to health is a major public health priority. Hence the Institute of Medicine (IOM, 2002) and the Department of Health and Human Services (USDHHS, 2000) are responsible for reducing health disparities by providing strategies to improve health care accessibility (AHRQ, 2002; IOM, 2002). Access to health care is a difficult phenomenon to measure. Primarily, this is because accessibility is not only a multidimensional process that focuses on quality of care given to individuals but also, it involves geographical accessibility, financial accessibility, acceptability of service and the right type of care given to anyone that needs them (Peters et al., 2008). One of the efficient ways to measure spatial

accessibility is by addressing geographical barriers such as distance and time (Cromley and McLafferty 2012; Guagliardo, 2004). Prior studies have shown that the frequency of a population in need of health care services decrease with increase in travel distance to health centers. Hence shorter distances facilitate frequent visits to health centers and better health conditions. For instance, a study by Buchmueller et al. (2006) revealed that most people who are very far from hospitals record the highest mortality rate resulting from heart attacks and unintentional injuries.

The built environment can be thought of as a foundation for health and wellness since the way neighborhoods are constructed have a significant impact on both the physical and mental health of an individual. Furthermore, the built environment determines the lifestyle and choices of people that results in either beneficial or adverse health outcomes at the individual and community level (Renalds et al., 2010). Neighborhoods or residential areas appear to be potentially relevant context since they have both physical and social attributes that could practically affect the health status of individuals (Kawachi & Berkman, 2009). Different neighborhoods exposures have a strong impact on health status at varying levels of aggregation (Culhane & Elo, 2005).

Researchers in the United States that makes use of census data to define both neighborhood conditions and neighborhood boundaries have found an association between neighborhood deprivation and preterm birth (Holzman et al., 2009; Messer et al., 2008), low birthweight (Schempf et al., 2009), small for gestational age (Elo et al., 2009; Farley et al., 2006) and also neural tube defects (Grewal et al., 2009).

## Problem Statement

Adverse or poor birth outcomes such as low birth weight births (LBWBs, birthweight of less than 2500g or 5.5lbs) and preterm births (PTBs, when an infant is born before the 37<sup>th</sup> week of gestation) are a major public health issue in the United States (Su et al., 2018). According to the Centers for Diseases Control and Prevention (CDC), in 2015 preterm and low birthweight accounted for 1 in 10 and 1 in 12 newborn infants in the US respectively (CDC, 2018). Low birthweight and preterm birth causes ophthalmic, neurological, and pulmonary disorders which increases infants' risk of mortality and morbidity (WHO, 2002).

Infants born with low birth weight have a high risk of poor health in the long term which can be related to chronic diseases such as cardiovascular disease and Type II diabetes mellitus disease (Martin et al., 2013). In 2001, the cost of low birthweight and preterm births for infants that were hospitalized in the US totaled \$5.8 billion with cost per infant hospitalization highest for preterm infants. Preterm and low birth weight babies in the United States constitute about half of infants that are hospitalized (Russell et al., 2007). Aside from congenital malformations, low birth weight and preterm birth account significantly for the highest infant mortality rate in the United States (Mathews & MacDorman, 2013).

Surprisingly, both low birthweight and preterm birth rates in Michigan (between 2014 and 2016) are higher than the mean US rates for the same year periods. According to the Centers for Disease Control and Prevention, in 2016, the low birth weight rate for Michigan and the US was 8.5 and 8.2 respectively; while preterm birth rate in the same year was 10.1 and 9.9 for Michigan and US respectively (CDC, 2018).



In Kalamazoo, preterm birth and low birth weight are associated with about 57 percent of infant mortality (Kalamazoo County Health and Community Services, 2005). According to Kalamazoo County Health and Community Services, low birthweight (poor birth outcome) infants in Kalamazoo increased continuously from 6 percent to 9.3 percent between 1989 and 2015; a higher percentage than the rate of low birthweight infants for all of Michigan. Due to health disparities based on race, black women in Kalamazoo have about 1.6 times higher odds of delivering a low birth weight baby than white women. Surprisingly, black women who live in disproportionately white neighborhoods with high socioeconomic status actually have worse birth outcomes (Kothari et al., 2016). Moreover, factors in the environment such as health care access, transportation, socioeconomic status, residential segregation, exposure to crime, built environment and access to green spaces all affect the health of individuals living in it (Healthy People, 2020). The main goal of this research is to examine the spatial variation of low birth weight across the rural-urban continuum of Kalamazoo County to give a clear understanding of current patterns in the region.

This study will make use of retrospective birth data of mothers in Kalamazoo County from 2008 to 2011 obtained from the Michigan Department of Health and Human Services (MDHHS) to evaluate spatial variation of low birth weight and provide a clear understanding of current patterns that exist. Chi-square test of association would be used to examine the first hypothesis: (1) Low birth weight rate is associated with individual maternal characteristics in Kalamazoo County. Ordinary least square and geographically weighted regression approach will be used to examine the second and third hypothesis: (2) Low birth weight varies spatially across the rural – urban county of Kalamazoo and (3) Low birth weight varies spatially across Kalamazoo County with respect to socioeconomic status, housing types and accessibility.

## Objectives and Research Questions

The main aim of this research is to evaluate the variation in low birth weight outcomes in Kalamazoo County to improve understanding of current patterns. This study will contribute to analyzing data at a local scale to plan interventions to reduce disparities in low birth weight in Kalamazoo County. To achieve this goal, these research questions will be examined:

1. Is low birth weight rate associated individual maternal characteristics?
2. Does low birth weight vary spatially across Kalamazoo County?
3. Are low birth weight rate variations related to socioeconomic status, housing types and transportation accessibility?

In addition to the research questions, four main objectives will be achieved in this research study.

The objectives are as follows:

- a) Statistically assess the association between maternal characteristics and low birth weight at the individual level.
- b) Geocode and map both the incidence of low birth weight rates (2008 -2011) and statistically significant block group variables utilizing ArcGIS 10.6.1 to visualize the spatial variations and patterns across the study area.
- c) Run an ordinary least square and geographically weighted regression using SPSS and GWR 4.0 software respectively. Ordinary least square and geographical weighted regression models were used to examine the linear and spatial relationship between low birth weight rates and the independent variables at the block group level.

- d) Run independent sample t-test using SPSS to analyze the association between block group variables at different thresholds and low birth weight rates at the block group level.

### Study Area

Kalamazoo County is located in Southwest Michigan. The total population of the county is about 262,985 with 81.5 percent (Caucasian and non-Hispanic) white, 11.7 percent (African Americans and non-Hispanic) black, 3.5 percent two or more races, 2.8 percent Asian, 0.5 percent American Indian and Alaska Native, 0.1 percent Native Hawaiian and Other Pacific Islander (US Census Bureau, 2017). The four major cities in the county are Kalamazoo, Portage, Galesburg and Parchment (Figure 1).

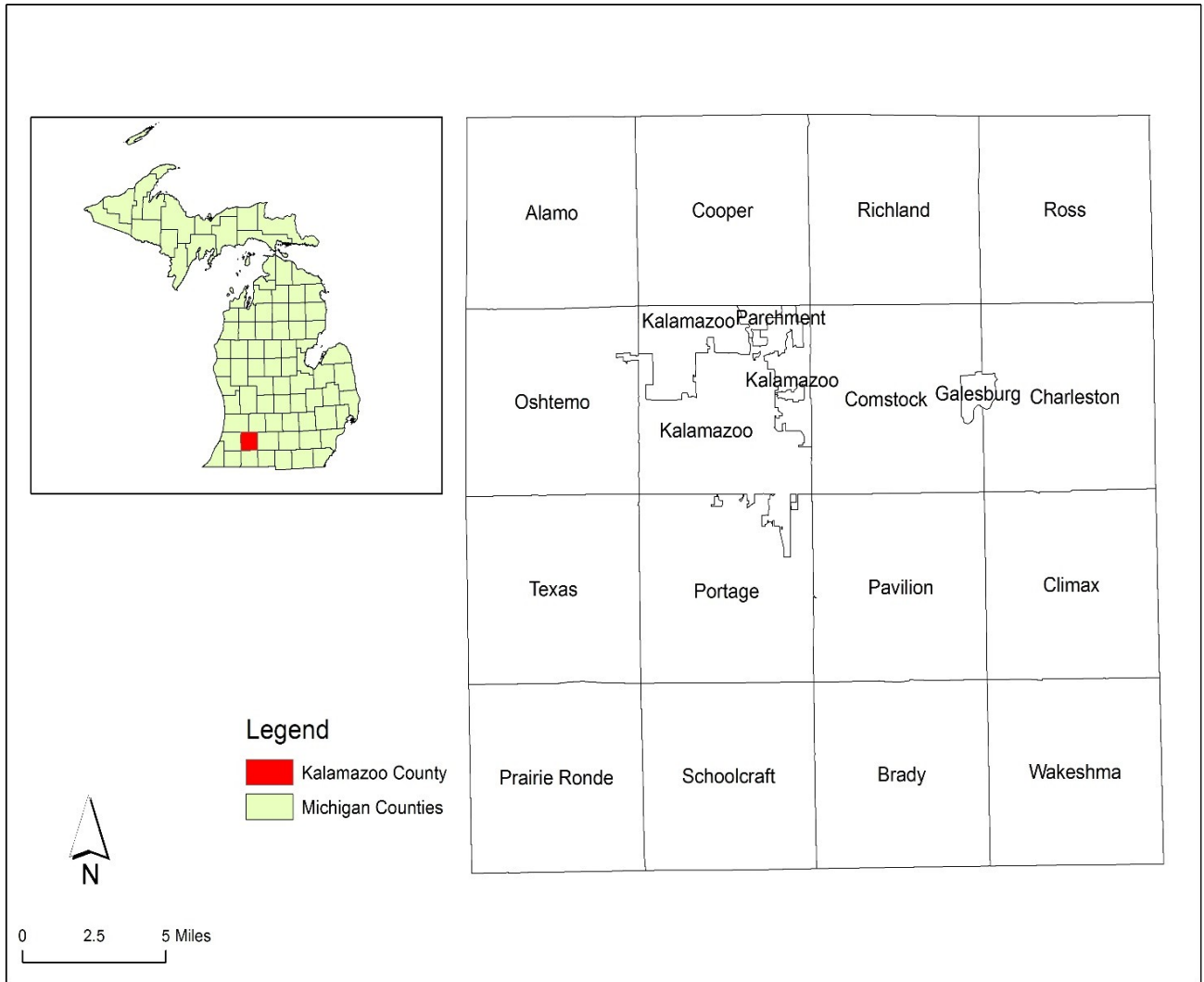


Figure 1. Minor civil divisions of Kalamazoo County, Michigan. Source: Michigan Geographic Data Library.

## CHAPTER II

### LITERATURE REVIEW

This chapter elaborates on existing literature based on the subject matter of this research. It highlights disparities in birth outcome emphasizing associated risk factors. The health and accessibility section focuses on ways in which accessibility can contribute to disparities in health; the geography and public health section focuses on ways in which GIS can be utilized in public health research. The chapter ends with a section on disparities in health and variations in health among different populations discussed more broadly.

#### Disparities in Birth Outcome

The health care system in the United States identifies the quality of maternal and infant health as a major problem even though it is regarded as a priority in Healthy People 2000 Program (U.S. Department of Health and Human Services, 1991 [DHHS]). Research studies on birth outcomes in the US by public health statisticians have been associated with either race or ethnic group. However, studies on disparities in birth outcome related to socioeconomic information have broadly been restricted to studies regarding the educational status of mothers. Other research finds differences in birth outcomes as a result of differences in socioeconomic level, education, race and ethnic group of individuals, and also unhealthy behaviors that affects an individual's health due to trends in the society (Blumenshine et al., 2010). Low birth weight and preterm are both forms of unfavorable birth outcomes that affect the health of the individual during infancy, childhood and even adulthood. Hence, subsequent assessment or evaluations must target interventions to mitigate socioeconomic discrepancies in birth outcomes to increase long term health of the population (Blumenshine et al., 2010).

In the US, studies show that there are variations in birth outcomes between white and black babies. Even though it is an enigma trying to understand why black babies are prone to greater risk factors related to birth outcomes unlike white infants., most studies place emphasis on risk factors like maternal risky behavior, prenatal care and also socioeconomic status at the time of pregnancy to be responsible for these disparities (Lu & Halfon, 2003).

According to the Center for Diseases Control and Prevention (CDC), preterm birth is defined as when a baby is born before 37 weeks of pregnancy, while a baby born less than 2500 grams, or 5.5lbs, is classified as a low birth weight baby. In the US, 1 out of every 10 infants born is born preterm (CDC, 2018). The birth rates of preterm infants were reduced from 2007 to 2014, with a significant decrease in number of births to young mothers and teens (CDC, 2018). Preterm and low birth weight babies represented 17% of infant deaths in 2015. Moreover, preterm birth rates among African-American women (14%) increased by 50 percent as compared to rate of preterm birth rates among white women (CDC, 2018). In 2016, about 3,945,875 births were registered in the US, while infants with low birth weight (8.17%) increased by 1% as compared to those of low birthweight in 2015 (8.07%); preterm birth rates in 2016 (9.8%) was greater than 2015 (9.63%) (Martin et al., 2015). Among race with non-Hispanic origins, LBW levels ranged from 6.97% to 13.68% for non- Hispanic white women and non-Hispanic black women respectively ( Martin et al., 2015).

In the US, there are inequalities in birth outcomes between black and white Americans. The rate of infant mortality in black Americans is 2.4 times that of white Americans (Kung et al., 2008). Ely et al in 2014, conducted a research study in the US and classified infant mortality rates into groups such as small and medium cities, rural areas and large urban with respect to mother's age, baby's death age and race and Hispanic origin. The research showed that rural counties

recorded higher mortality rates for babies as compared and infant's mortality rates decreasing with increase in urbanization level. However, this result does not accurately represent the situation in America. Preterm and low birth rates, which are predominantly higher among black Americans have been used to analyze the racial disparities in infant mortality rates (Martin et al., 2009). In order to mitigate or reduce racial disparities (infant mortality), it is very essential to identify the factors that contribute greater risk of adverse birth outcomes during pregnancy in black American Women (Rosenthal & Lobel, 2011). Insurance coverage has been posited as one source of disparity. While Medicaid has increased broad scale coverage of pregnant women, in the 1980s research revealed that black American women were refused treatment during pregnancy because they were uninsured (lacked health insurance) or health practitioners thought they were not honest about their insurance coverage (Davis 1984).

Women who live in cities experience different birth outcomes from women living in rural areas. This can be attributed to variations in ethnic groups and variable socioeconomic levels of people living in both urban and rural areas, as well as accessibility to health facilities. It is also imperative to curb significant disparities in birth outcomes (low birth or pregnancy weight and history of poor diet) between rural and urban women as it is among women of different racial backgrounds. These different forms of disparities will require different types of mediation in order to ameliorate pregnancy outcomes (Alexy et al., 1997).

Rural women account for about 20% of all births in the US, but less attention is given to pregnant outcomes in the rural areas as compared to studies in urban areas often because there are simply less births in the rural areas of any region (Hart et al., 2005). Apart from maternal characteristics of individuals, rural–urban residence can in some settings be used as an important predictor of low birthweight (Hillemeier et al., 2007). Rural women with low levels of

neighborhood income and educational background are highly vulnerable to adverse birth outcomes, like preterm birth, still birth and small-for gestational age (SGA). Individual level socioeconomic status (SES) is key in determining populations at risk of poor birth outcomes. According to Hillemeier et al. (2007), even though risk of adverse birth outcomes (low birthweight and preterm) in women are very high in rural areas, not all types of rural areas are associated with high prevalence of poor birth outcomes. High risk of low birthweight and post neonatal mortality are experienced by individuals who live in rural poverty counties than residents of non-poverty rural counties (Medicine, 2008). Individual-level socioeconomic status and race risk factors increase geographical disparities of urban and rural birth outcomes (Kent et al., 2013). According to Kent et al. (2007), densely populated and isolated rural areas have high percentages of adverse birth outcomes of preterm birth and low birthweight. Rural women, unlike urban women experience lower quality in health care due to factors such as political issues, infrastructural problems, educational level as well as socioeconomic status of people living in these rural areas (Weinhold & Gurtner, 2014).

### Health and Accessibility

In recent times, accessibility measures has been the prime focus of Departments of Transportation and Metropolitan Planning Organizations in the US, although accessibility is notoriously difficult to quantify (Handy & Niemeier, 1997). The process of visiting a facility such as shopping mall, health facility, or any given location with considerable ease is termed accessibility (Bentham, 1997).

Accessibility to health care is defined as whether a population with health care needs can successfully use the available medical system (Aday & Andersen, 1974). Factors like supply of physicians and needs of a population influence accessibility to health facilities in the US. Poor



access to health facilities is more common for rural residents than for urban mothers (Luo, 2004). In rural areas, specifically remote ones, there is low accessibility to health facilities as a result of lack of public transportation (Lovett et al., 2002). Poor physical accessibility accounts for poor health outcomes because it reduces the use of services by residents of a community (Bentham, 1997).

The ease with which individuals of a given location can reach medical facilities and services is termed spatial accessibility to healthcare (Hewko et al., 2002). Geographic distance is an important function of spatial accessibility in explaining the interaction between population demands and health services (Joseph & Bantock, 1982). Spatial accessibility can be categorized into a contextual variable like travel time or travel distance of a population to the closest health facility (Brabyn et al., 2002).

Even though measures of spatial accessibility can be used to inform decisions on urban policies such as identifying areas low access to amenities, neighborhood-level spatial accessibility indices are prone to methodological problems (Handy & Niemeier, 1997). Accessibility to health services should not be limited in scope to only spatial and temporal analyses; but also must be analyzed in terms of in terms of availability of human resources, demographic structure, existence and endowment of medical offices, and local conditions such as socioeconomic as well as cultural or specific aspects of morbidity (Ursulica, 2016).

Many Americans face transportation problems which are barriers to health care access (Wallace et al., 2005). Since the 19<sup>th</sup> century, distance to health facilities has been a barrier to health care in the US (Hunter et al., 1986). There are significant differences between the health care access in rural and urban areas because of the dispersion of the population in rural environments. Multiple factors lead to difficulties in rural residents accessing health facilities.

Problem include a scarcity of services, a lack of trained physicians, insufficient public transport, and poor availability of broadband internet services. Unlike urban residents, rural residents have poorer health and difficulties in retaining physicians (Douthit et al., 2015). There must be improvements to ameliorate difficulty in accessibility of health facilities by rural patients. Studies have shown that some disparities in rural health care have been reduced through the implementation of the Patient Protection and Affordable Care Act (Douthit et al., 2015).

### Geography and Public Health

According to the World Health Organization (WHO), health is defined as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO, 1948). Irrespective of an individual’s race, religion, political belief, economic or social condition, people have a fundamental right to enjoy the highest standard of health which leads to the accomplishment of peace and security (WHO, 1948).

Geography and health are inherently connected. The disparities in health outcomes that we experience are influenced by factors such as the air we breathe, the food we eat, the pathogens we are exposed to and accessibility to health care treatment. All of the above factors depend on where we are born, inhabit, or work (Tunstall et al., 2004). Spatial scales are important to health service provision and public health implementation because, the geographic context of health issues have a direct influence on health policies (Asthana et al., 2002). Geographers and social scientists claim that the spatial characteristics of a place influences health disparities because it contains social relations and physical resources (Jones & Moon, 1993). Health disparities are caused by individual characteristics and the setting in which they are situated. Hence geography can be used to explain the inequalities in health experiences of individuals and communities (Curtis & Jones, 1998). Places have a link or relation to one another and these links determine their

influence on health. Places are characterized by physical fabrics which acts as the direct determinant of public health (Tunstall et al., 2004).

Spatial analysis is important in public health because it enables us to make informed decisions which leads to the development of public health policies at an appropriate scale based on evidence. Geography also plays a major role in public health by allowing us to understand certain disease risk factors, environment and occupation interact with the physical environment (Dalhlgren & Whitehead, 1991). Collaboration between health specialists and geographers regularly develop innovative approaches to solving complex problems and ultimately reducing health disparities (Dummer, 2008).

Geographic Information Systems (GIS) can be used for organizing, documenting, analyzing and presenting spatial information. GIS incorporate a set of tools that have numerous techniques like the ability to overlay spatial data layers and can be used in public health GIS, (Twigg, 1990). GIS can be used extensively for spatial analysis in the context of public health where it is applied to a variety of health related phenomena (Bertazzon, 2014). Recent developments in GIS and computing capacity have made it suitable to measure accessibility to health facilities related to community resources at the neighborhood level (Pearce et al., 2017). GIS can be useful in health care delivery when it combines with spatial analytical methods. Geographic Information System have been useful in disease surveillance programs. When the location and disease information of sentinel physician is connected to a Geographic Information System, the GIS can provide data to identify patterns of disease and locations of emerging disease problems (Moore & Carpenter, 1999).

## Disparities in Health

Health disparities exist between different populations and have been a major issue for years with minorities in their communities. Apart from disparities in birth outcomes described at the beginning of the chapter, this section focuses on widespread disparities that give context to birth disparities. Since 1960, the mortality rate for blacks have been 50 percent higher than that for whites, and the infant mortality rate for blacks has been twice as high as that for whites (Woolf & Braveman, 2011). Health disparities exist even in health care systems that offer patients similar access to care, such as the Department of Veterans Affairs, which suggests that disparities originate outside the formal health care setting (Woolf & Braveman, 2011). Health has a particular value for individuals because it is essential to an individual's well-being and ability to participate fully in the workforce and a democratic society. Ill health means potential suffering, disability, and/or loss of life, while threatening one's ability to earn a living, and is an obstacle to fully expressing one's views and engaging in the political process (Braveman et al., 2011). Health disparities does not only occur among populations of different race and socioeconomic status but also is affected by social systems. Studies show that education, like income, has a large influence on health (Woolf & Braveman, 2011). An extensive literature documents large health disparities among adults with different levels of education (Woolf & Braveman, 2011). Persons without a high school diploma or equivalent are three times as likely as those with a college education to die before age sixty-five (Woolf & Braveman, 2011). Research have shown that the average twenty-five-year-old with less than twelve years' education lives almost seven fewer years than individuals with at least sixteen years' education (Woolf & Braveman, 2011). The health of infants is also strongly linked to their parents' education (Woolf & Braveman, 2011).

Researchers commonly define the term “health disparities” as health differences across different population groups, as has been done by some federal agencies. This encompasses the entire domain of epidemiology, which is the study of the distribution of diseases and risk factors across different populations (Braveman et al., 2011). Studies show that the definitions proposed were designed to clarify the concepts of health disparities and health equity in ways that could stand up to rigorous conceptual scrutiny as a basis for guiding policy and practice and also ensuring accountability, which requires clear criteria for measurement (Braveman et al., 2011). The best way to define health disparities is to say the worst health among socially disadvantaged populations.

Eliminating disparities in health is one of the major goals of Healthy People 2020 Program (Braveman et al., 2011). Health differences adversely affecting socially disadvantaged groups are particularly unacceptable because ill health can be an obstacle to overcoming social disadvantage (Braveman, 2011). Studies of racial health disparities are at a crossroads (Bratter & Gorman, 2011). Persistent differences in mental and physical health show the various ways by which racial disparities is related to well-being (Bratter & Gorman, 2011). On the other hand, increasing attention toward identities spanning racial boundaries has caused researchers to question the nature of racial distinctions (Bratter & Gorman, 2011). Considering race from a biological perspective to health; studies illustrate that the attribution of racial disparities in health to inherited biological difference in susceptibility to disease is rooted in a long- standing US tradition that continues to the present day (Kawachi et al., 2005). Notions of racial disparities have even risen to prominence in recent years in the wake of the human genome project and the search for race-based genetic susceptibility to diseases such as hypertension and diabetes (Kawachi et al., 2005).

Differences in socioeconomic status are a major cause of racial disparities in health care and health outcomes (Weisfeld & Perlman, 2005). Moreover, research illustrated by the Institute

of Medicine report concluded that racial and ethnic disparities in health care are associated with socioeconomic differences and tend to diminish significantly, and in a few cases, disappear when socioeconomic factors are controlled (Weisfeld & Perlman, 2005). The ways in which socioeconomic status affects health are extraordinarily complex. These include factors such as access to health insurance, geography, and a sense of personal autonomy and control over one's life. Generally, it is difficult to control adequately for all of the manifold mechanisms by which socioeconomic status can affect health and health care (Weisfeld & Perlman, 2005).

According to some researchers, racial or ethnic differences in education and income could largely explain the poorer health outcomes for black and other minorities (Woolf & Braveman, 2011). The high school dropout rate is 18.3 percent among Hispanics, 9.9 percent among blacks, and 4.8 percent among non-Hispanic whites (Woolf & Braveman, 2011). Blacks and Hispanic households earned about two-thirds the income of non-Hispanic whites and are three times as likely to live in poverty. A web of conditions in which education and income are elements of a web of social and economic conditions that affect health in complex ways over a lifetime (Woolf & Braveman, 2011). These conditions include differences in employment rate, levels of wealth, neighborhood characteristics, and social policies as well as culture and beliefs about health. (Woolf & Braveman, 2011). People with low education and limited income are more likely than their better-educated, higher-income counterparts to lack a job, health insurance, and disposable income available for medical expenses. Studies also show education and income are also associated with behaviors that affect health (Woolf & Braveman, 2011).

## CHAPTER III

### METHODOLOGY

This chapter focuses on the methods and the research design implemented to conduct the research. It elaborates on the study design and sample population, data collection and measures, variables (outcome variable and predictor variables), GIS methods and statistical analysis.

#### Study Design and Population

This study was conducted as a multi-level analysis. The data was compiled by combining all births from 2008 to 2011 in Kalamazoo County. Birth records data were retrieved from the Michigan Department of Health and Human Services. The study was approved by the Human Subjects Institutional Review Board of the Western Michigan University.

#### Measures and Data Collection

This research study was conducted using individual birth records of mothers from 2008 to 2011 in the study area. The demographic variables extracted from the data at the individual level for the purposes of this research include maternal age, maternal education, maternal race, maternal address, and infant birth weight (outcome variable), as well as whether the birth was paid for by Medicaid. Medicaid is a national public health insurance program for people with low income. Medicaid is a proxy for maternal socioeconomic status at the individual level. Hence women on Medicaid- paid birth were considered to be in the low SES group; while women on non- Medicaid (private insurance) birth were categorized as high SES.

Race was grouped into two main categories; white (Caucasian or non-Hispanic white) and black mothers (African American or non- Hispanic black). There are other populations (racial

groups) in Kalamazoo County but this research focused on only non- Hispanic white and non- Hispanic black. Age of mothers were classified as less than 20, 20-24 years and greater than 35 years. Mother's education was categorized into less than high school completion, high school completion, some college or associate degree, and bachelor's degree or higher.

### Geocoding of Low Birth Weight Cases

The individual birth records of mothers were geocoded with ArcGIS 10.6.1 using maternal residence address at the time when they gave birth to infant from 2008 to 2011. The geocoded results yielded an accuracy of 90%. The addresses of maternal residence that could not be geocoded in an automated fashion were manually located with the help of Google maps. After address matching was complete, the individual birth records of women from 2008-2011 in the study area (Kalamazoo County) were joined to the relevant U.S. Census 2010 block group identifiers through a spatial join using an industry standard geographic information system (ArcGIS 10.6.1).

### Block Group Variables

Kalamazoo County has about 189 census block groups. After joining the individual birth records of women to the US Census 2010 block group, the low birth weight cases at the individual level were aggregated at the block group level. Percentage low birth weight was aggregated at the block group level by dividing the number of low birth weight cases in each block group with the corresponding total number of births in each block group. A variety of block group variables were downloaded from the American Community Survey (ACS). The American Community Survey is the source that provides information about America's changing population, workforce, and housing information. For purposes of this research, ACS block group variables were used to



describe the characteristics of neighbors living near an expectant mother. In no way does this research attempt to consider spatially defined neighborhoods as might be defined by a city in a broader sense. . The neighborhood level predictors were abstracted from the block group data set from ACS five- year estimate for 2013 (2009-2013). Neighborhood level variables used include, housing unit type, median household income, unemployment (population 16 years and over unemployed), and educational attainment of mothers.

At the block group level, the average number of doctors that can be accessed from the centroid of the block group was computed for bus and private cars based on travel time. With respect bus, average number of doctors that can be accessed from the centroid of block groups to health centers for 30 and 60 minutes was computed. For car, the average number of doctors that can be accessed from centroids to health centers for 15 and 30 minutes were computed (Baker & Ayon, 2018).

Household unit types include renter occupied and mobile home units. Income was classified as median household income for each block group. Median household income is consistent Medicaid at the individual level. Educational status (females 25 years and over) at the block group level was only less than less than high school females and this is consistent with one out of four educational levels at the individual level. Apart from median household income, all the block group variables selected were standardized to rates by computing the percentage for each block group.

## Statistical Analysis

The statistical analysis employed in this research study was performed using SPSS and GWR 4.0 statistical software. The data was first analyzed at the individual and subsequently at the block group level (neighborhood level). For this research, continuous and categorical variables were used at the individual and neighborhood levels respectively.

At the individual level, it was hypothesized that low birth weight is associated with individual maternal characteristics. Chi - square test of association was used to test the association between maternal characteristics (maternal age, maternal race, maternal education, Medicaid) and the low birth weight. The output of this test showed which of the maternal characteristics is significant with low birth weight.

Pearson's correlation was used to test the correlation between independent variables used for analyses at the block group level. The test result showed the independent variables that have high correlation between themselves. In order to avoid problems with multi collinearity, principal component analysis (PCA) was run on three main variables at the neighborhood levels, thus percent less than high school, median household income and percent unemployment. Only one component was extracted and this was based on components with Eigen values greater than 1.

At the block group level, the assumption made for the model to be developed was that, low birth weight vary spatially across Kalamazoo County with respect to socioeconomic status, housing types, and accessibility. Using SPSS and GWR 4.0 software, ordinary least square and geographically weighted regression models were developed respectively. The OLS model was used to examine the linear relationship between the independent variables and the percentage of low birth weight cases over the four-year period. The GWR model was used to examine and

explore the spatial relationship between the independent variables and the percentage of low birth weight cases. This helped to understand which predictors vary spatially with low birth weight at specific locations. All the variables in the model were tested at the 95 percent level of significance. The results of the analyses were used to answer the research questions of this research study and suggest ways to target interventions to reduce low birth weight incidence in the rural- urban county of Kalamazoo County.

Finally, using SPSS, independent sample t-test was run to examine if the block group variables were associated with low birth weight rates. The block group variables were dichotomized into “high” and “low” thresholds. Values of the block group variables were classified as “low” when less than 1 standard deviation below the mean; and “high” when greater than 1 standard deviation below the mean.

## CHAPTER IV

### ANALYSIS AND RESULTS

This chapter outlines and explains the results and analysis of this research study. The key areas that will be highlighted in this section include: descriptive analysis of low birth weight cases in the study area; and results of spatial and statistical analysis employed in this study.

#### Description of Low Birth Weight Data

The data used for this analysis were obtained from the Michigan Department of Health and Human Services. The total number of birth cases recorded in the study area from 2008 to 2011 were 12,023. The birth records for the four-year period were restricted to only women who were Kalamazoo County residents when they gave birth to infants.

The final sample population drawn from the total population (N=12023) was selected based on three measures. The criteria for selection included: singleton live births limited to only black and white non-Hispanic mothers. Singleton is a term used to describe all live births where mothers deliver only one infant (as opposed to giving birth to twins, triplets, etc.). The final study sample of 10779 women delivered 637 infants (5.90%) with low birth weight (birth weight lower than 2500 grams). White non-Hispanic mothers accounted for 80.10% (n=8635) of the final study population, and about 19.9% (2144) represented black non-Hispanic mothers. Out of 637 low birth weight cases recorded, the final study sample of 8635 white women delivered 4.66% (n=402), while final study sample of 2144 black women delivered 10.97% (n=235).

Both low and normal birth weight cases were categorized according to characteristics of individual mothers during the four-year period in the county (Table 1). The individual level

characteristics include race (non-Hispanic black and white), age (less than 20, 20-34, and  $\geq 35$  years), educational level (Less than High school, High school, Some college or Associate degree and Bachelor's degree or Higher) and Medicaid status at the time of birth. Table 1 shows the maternal individual level characteristics with frequency and percentage of low and normal birth weight cases.

Table 1. Maternal individual level characteristics with low and normal birth weight cases from 2008 to 2011 in Kalamazoo County.

Individual Characteristics		Low Birth Weight (n=637)		Normal birth weight (n=10142)	
		No.	%	No.	%
Race	White	402	4.66%	8233	95.34%
	Black	235	10.97%	1908	89.03%
Age	< 20	106	10.20%	933	89.80%
	20 -34	467	5.45%	8095	94.53%
	$\geq 35$	64	5.44%	1113	94.59%
Education	Less than High school	145	11.48%	1118	88.52%
	High school	195	7.15%	2532	92.85%
	Some College or Associate degree	174	5.48%	3001	94.51%
	Bachelor's degree or Higher	123	3.40%	3491	96.60%
Medicaid	Medicaid birth	427	8.52%	4583	91.48%
	Non- Medicaid birth	210	3.64%	5559	96.30%

With respect to race, the frequency of white and black infants delivered with weight less than 2500 grams were 402 and 235, respectively. Although the frequency of low birth weight cases for white infants is almost twice that of black infants, the percentage of low birth weight cases for black infants (10.96%) was significantly higher than that of white infants (4.66%).

For age, the category with the highest frequency of low birth weight; thus 20 to 34 years, recorded about 467 cases, followed by mothers less than 20 years recording 106 cases, and the highest age category that comprise mothers greater than or equal 35, recorded the least with about 64 cases of low birth weight. In terms of percentage, mothers who are 20 to 34 years and greater than or equal to 35 years recorded about 5.45% and 5.44% of low birth weight respectively. However, mothers less than 20 years (< 20 years) obtained the highest percentage (10.20%) of low birth weight incidence, which is a little below twice the percentage of the other groups of age (20 to 34 years and  $\geq 35$  years).

Considering the four levels of education, mothers with a high school certificate recorded 195 cases, which is the highest frequency of low birth weight incidence for educational level. The next highest; mothers who attended some college or with an associate degree, also had 174 cases of low birth weight incidence followed by mothers with less than high school certificate recording 145 cases. Lastly, mothers with a bachelor's degree or higher recorded the least number of low birth weight cases with a frequency of about 123 cases. The percentage of low birth weight incidence for mothers with less than high school certificate, high school certificate, some college or associate degree and bachelor's degree or higher are 11.48%, 7.15%, 5.51% and 3.40% respectively.

Finally, in terms of Medicaid, mothers who delivered infants while on Medicaid recorded higher number of low birth weight incidence as compared to mothers without Medicaid. The

frequency of low birth weight incidence for mothers who delivered on Medicaid was 427 (8.52%). Mothers whose deliveries were not paid by Medicaid recorded 210 (3.64%) cases of low birth weight.

### Geocoding Results

Maternal addresses were matched to the road centerline file maintained by Kalamazoo County. Maternal addresses that could not be geocoded automatically were manually placed using knowledge of the area, Google maps and other supplementary data sources until 90% of the addresses were placed. The addresses or records that could not be geocoded had incomplete or missing addresses, post-office box addresses, or an address that could not be referenced to the street centerline file.

## Statistical Analysis: Individual Level

Table 2. Maternal race and low birth weight cross tabulation.

			Normal Birth Weight	Low Birth Weight	Total
Maternal Race	White	Count	8318	317	8635
		Expected Count	8236.9	398.1	8635
		% within Birth Weight	80.90%	63.80%	80.10%
	Black	Count	1964	180	2144
		Expected Count	2045.1	98.9	2144
		% within Birth Weight	19.10%	36.20%	19.90%
Total		Count	10282	497	10779
		Expected Count	10282	497	10779
		% within Birth Weight	100%	100%	100%

At the individual level, for the purposes of this research, it was hypothesized that individual characteristics such as maternal age, maternal race, maternal education and Medicaid status at time of delivery (whether or not mothers were on Medicaid insurance) were associated with low birth weight. The Chi-square test of association was used to test if low birth weight was associated with individual maternal characteristics.

The results are twofold. The first output shows the observed and expected frequencies. The second output gives the results of the chi-square test. The expected and observed count in regards to low birth weight for white race is 398.1 and 317 respectively. From the results it can be



deduced that the observed count is less than the expected count. This implies that the frequency of low birth weight cases was less than the expected frequency. The percentage of low birth weight for white race as compared to the sum of low birth weight (497) was about 63.80%.

For black mothers, the expected frequency for low birth weight is 98.9 while the observed count for low birth weight was 180 (Table 2). Unlike white mothers, the frequency of observed count (180) was greater than the expected count (98.9). This implies that there were more cases of low birth weight among black women than expected. The percentage of low birth weight incidence for black women was 36.20%.

A chi-square test of association was run to test if low birth weight was associated with maternal race. The frequencies of low birth weight in black and white mothers were compared. A significant association was found ( $X^2 (1) = 87.16, p < 0.001$ ) between low birth weight and maternal race (Table 3).

The value of chi-square was influenced by the difference between observed (180) and expected (98.9) frequencies of low birth weight for black mothers (Table 2).

Table 3. Chi- square test for maternal race and low birth weight.

	Value	df	Asymptotic Significance ( 2 sided)	Exact sig. ( 2 sided )	Exact sig. ( 1 sided)
Pearson Chi-Square	87.16	1	0.000		
Continuity correction	86.09	1	0.000		
Likelihood ratio	75.30	1	0.000		
Fisher's Exact test				0.000	0.000
Linear-by-Linear association	87.15	1	0.000		
Number of Valid Cases		10779			

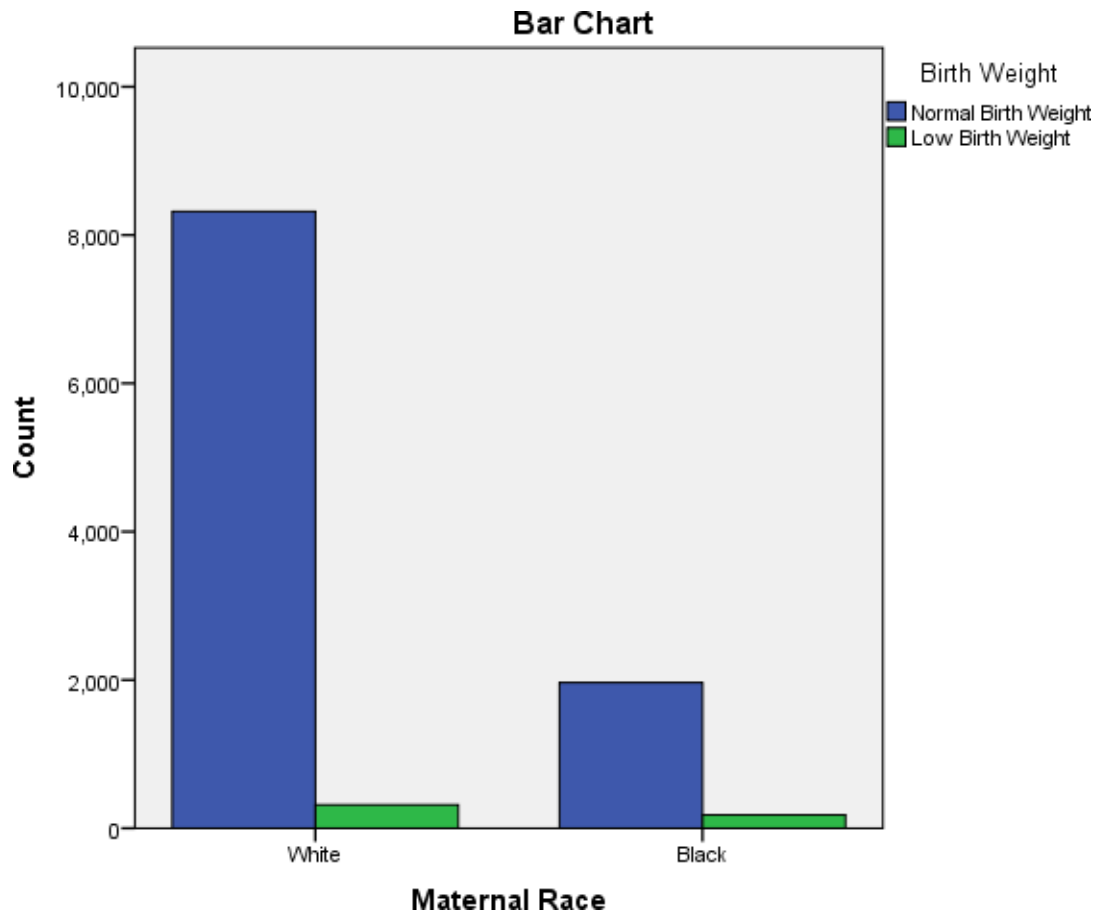


Figure 2. Bar chart of low and normal birth weight by race (black and white).

The bar chart (Figure 2) is the output of the chi-square test. It shows the frequency of observed normal birth weight and low birth weight with respect to black and white mothers. According to the chart white mothers delivered 8318 normal weight infants and 317 low birth weight infants (Figure 2). Black mothers delivered about 1964 normal weight babies and 180 low birth weight babies. Since Kalamazoo County has a greater percentage of white than black, the chart shows more counts for normal and low birth weight for white mothers than black mothers.

Table 4. Maternal education and low birth weight cross tabulation.

			Normal Birth Weight	Low Birth Weight	Total
Maternal Education	Less than high School	Count	1145	118	1263
		Expected Count	1204.8	58.2	1263
		% within Birth Weight	11.1%	23.7%	111.7%
	High school	Count	2579	148	2727
		Expected Count	2601.3	125.7	2727
		% within Birth Weight	25.1%	29.80%	25.3%
	Some College or Associate degree	Count	3048	127	3175
		Expected Count	3028.6	146.4	3175
		% within Birth Weight	29.6%	25.6%	29.5%
	Bachelor's degree or Higher	Count	3510	104	3614
		Expected Count	3447.4	166.6	3614
		% within Birth Weight	34.1%	20.9%	33.5%
Total		Count	10282	497	10779
		Expected Count	10282	497	10779
		% within Birth Weight	100%	100%	100%

Table 4 shows the cross tabulation between maternal education and low birth weight incidence. Maternal education is categorized into less than high school, high school, some college or associate degree and bachelor's degree or higher. For women in less than high school, the expected frequency (58.2) for low birth weight was lower than observed frequency (118). Also, women who in the high school category recorded more for observed frequency (148) than expected frequency (125.7).

However, some college or associate degree and bachelor's or higher degree recorded less cases than expected. Women with a bachelor's degree or higher recorded 104 cases for observed as against 166 expected cases. Finally, the frequency of observed and expected cases for some college or associate degree 127 and 146.4 respectively. Of all four levels of education, women who have completed high school recorded the highest percentage of low birth weight with a percentage of 29.8%, followed less than high school with 23.7%, some college or associate degree with bachelor's degree with 25.6% and bachelor's degree or higher with a percentage of 20.9%.

Table 5. Chi –square test for maternal education and low birth weight.

	Value	df	Asymptotic Significance ( 2 sided)
Pearson Chi- Square	95.808	3	0.000
Likelihood ratio	85.229	3	0.000
Linear-by-Linear association	85.258	1	0.000
Number of Valid Cases	10779		

The frequency of low birth weight incidence for the four categories of education (less than high school, high school, some college or associate degree, and bachelor’s degree or higher) were compared. A significant relationship was found ( $X^2(3) = 95.808, p < 0.001$ ) between maternal education and low birth weight (Table 5). The value of chi-square was influenced by the difference in low birth weight cases (observed and expected) for less than high school and high school mothers.

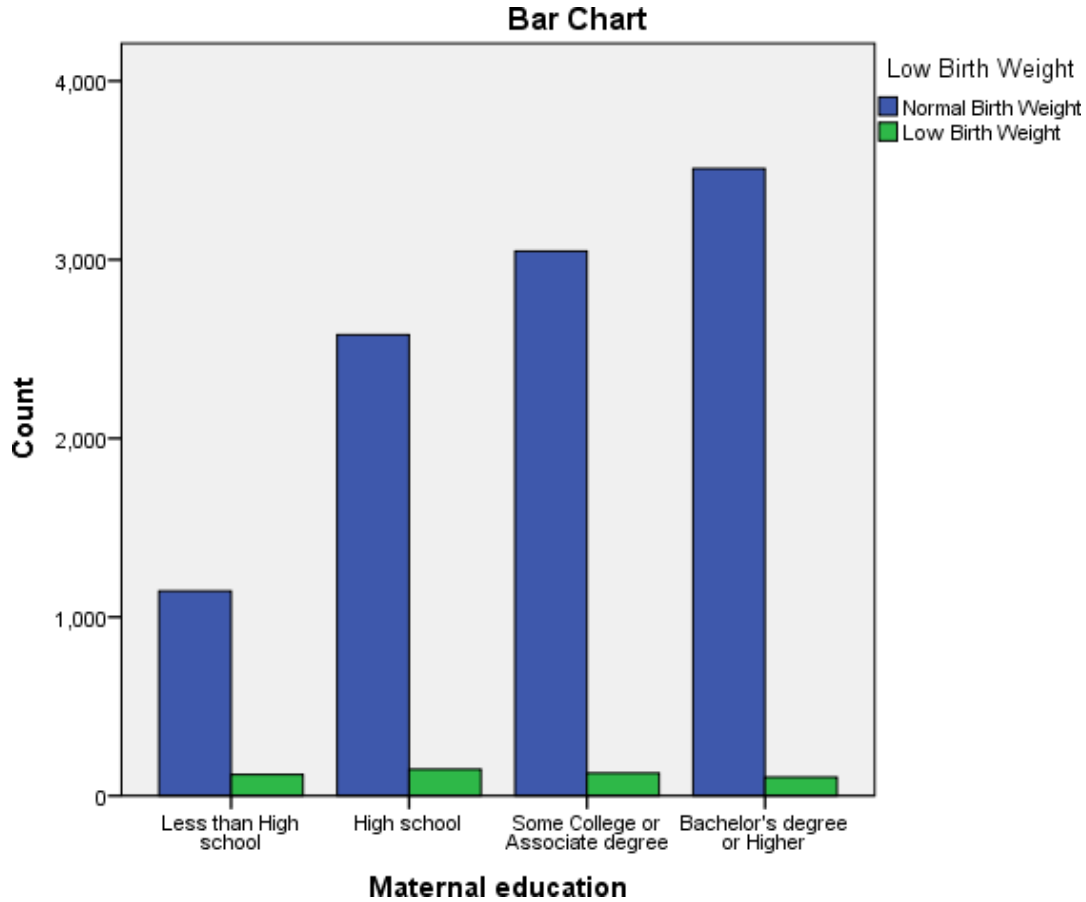


Figure 3. Bar chart of low and normal birth weight by maternal education.

Figure 3 describes birth weight (low and normal birth weight) according to maternal education. The chart shows the observed frequencies for low and normal birth weight in relation to maternal education. The chart shows that for high school, out of 2727 infants delivered, 148 were low birth weight infants, and 2579 infants were normal weight infants. Out of 1263 infants delivered by women with less than high school education, 1145 and 118 were recorded as normal and low birth weight infants respectively. For some college or associate degree category, 3175 infants were delivered with 127 low birth weight and 3048 normal birth weight. The total number of infants delivered by women with bachelor's degree or higher is 3614, of the total 104 were low birth weight infants and 3510 were normal birth weight infants.

Table 6. Maternal age and low birth weight cross tabulation.

			Normal Birth Weight	Low Birth Weight	Total
Maternal Age	< 20 years	Count	880	79	1039
		Expected Count	991.1	47.9	1039
		% within Birth Weight	9.30%	15.90%	9.60%
	20 to 34 years	Count	8190	373	8563
		Expected Count	8168.2	394.8	8563
		% within Birth Weight	79.70%	75.10%	79.40%
	>= 35 years	Count	1132	45	1177
		Expected Count	1122.7	54.3	1177
		% within Birth Weight	11.00%	9.10%	10.90%
Total		Count	10282	497	10779
		Expected Count	10282	497	10779
		% within Birth Weight	100%	100%	100%



The cross tabulation of low birth weight versus maternal age is shown in Table 6. Maternal age was categorized into less than 20 years (< 20 years), from 20 to 34 years (20-34 years) women who were 35 years and above ( $\geq 35$  years). Women in the less than 20 years age category recorded observed frequencies (79) for low birth weight incidence higher than expected frequency (47.9). Women in the 20 to 34 years age category recorded less observed frequency for low birth weight than expected frequency; 373 observed as opposed to 394.8 expected frequency. The case is no different for women who are 35 years or above. The frequency of low birth weight cases recorded (45) was higher than expected (54.3).

Overall, in the age category, women who were in the 20 to 34 years category group had the highest rate of low birth weight incidence with a percentage of 75.10 % (Table 6). The group with the next highest rate was women who were less than 20 years with a percentage of 15.90%. Women who were 35 years and above recorded the least rate with a percentage of 9.10%.

Table 7. Chi-square test for maternal age and low birth weight.

	Value	df	Asymptotic Significance ( 2 sided)
Pearson Chi- Square	24.081	2	0.000
Likelihood ratio	20.876	2	0.000
Number of Valid Cases	10779		

After comparing the low birth weight incidence for the three categories of maternal age, a significant relationship was found ( $X^2(2) = 24.081, p < 0.001$ ) between maternal age and low birth weight (Table 7).

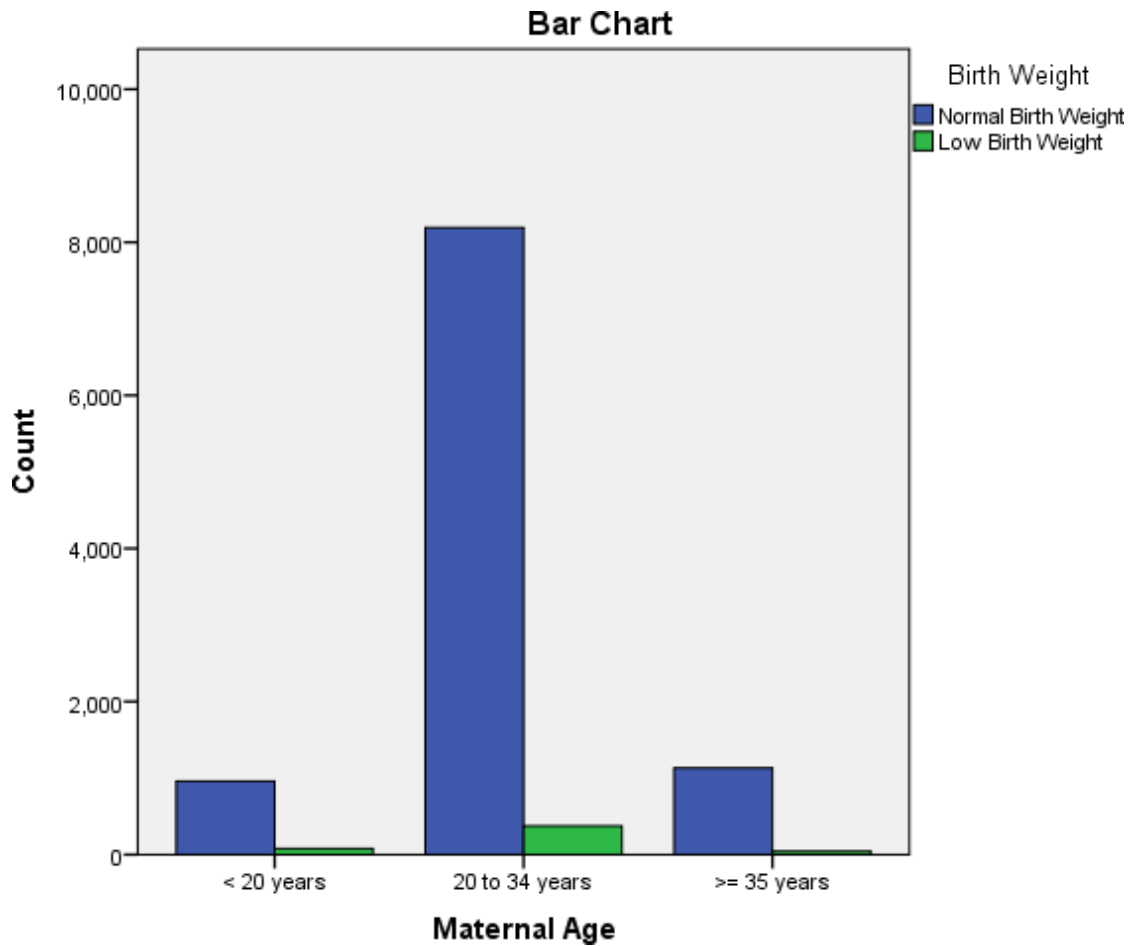


Figure 4. Bar chart of low and normal birth weight by maternal age.

The chart (Figure 4) categorizes maternal age into frequency of normal and low birth weight infants delivered by women. For women less than 20 years, out of 1039 infants delivered, 880 normal birth weight infants were delivered and 79 low birth weight infants were delivered. Considering women in 20 to 34 age category, 373 low birth weight infants were delivered and 8190 infants with normal birth weight were delivered. Hence a total of 8563 infants were delivered. For the last group, thus 35 years and above, a total of 1177 infants were delivered, 45 were low birth weight infants and 1132 were normal birth weight infants.

Table 8. Medicaid and low birth weight cross tabulation.

			Normal Birth Weight	Low Birth Weight	Total
Medicaid	Medicaid Birth	Count	4880	330	5010
		Expected Count	4779	231	5010
		% within Birth Weight	45.50%	66.40%	46.5%
	Non-Medicaid Birth	Count	5602	167	5769
		Expected Count	5503	266	5769
		% within Birth Weight	54.50%	33.60%	53.50%
Total		Count	10282	497	10779
		Expected Count	10282	497	10779
		% within Birth Weight	100%	100%	100%

Table 8 shows the interaction between women who have Medicaid and low birth weight cases. The observed frequency of low birth weight infants for women who delivered on Medicaid insurance was higher than the expected frequency. For Medicaid delivery, the expected frequency for low birth weight cases was 231 and observed frequency was 330. However, for non-Medicaid birth (private insurance), the observed frequency of low birth weight infants (167) was less than the expected frequency (266). Also Medicaid delivery had a higher rate of low birthweight infants as compared to non-Medicaid delivery; 66.40% for Medicaid birth and 33.60% for non-Medicaid birth (Table 8).

A chi-square test of association was calculated comparing the frequency of low birth weight infants for women with Medicaid and non-Medicaid (private insurance) .After comparing the low birth weight incidence for the two categories, a significant relationship was found ( $X^2(1) = 83.103, p < 0.001$ ) between Medicaid birth and low birth weight incidence (Table 9).

Table 9. Chi-square test for Medicaid and low birth weight.

	Value	df	Asymptotic Significance ( 2 sided)	Exact sig. ( 2 sided )	Exact sig. ( 1sided)
Pearson Chi- Square	83.103	1	0.000		
Continuity correction	82.266	1	0.000		
Likelihood ratio	83.760	1	0.000		
Fisher's Exact test				0.000	0.000
Linear-by-Linear association	83.095	1	0.000		
Number of Valid Cases		10779			

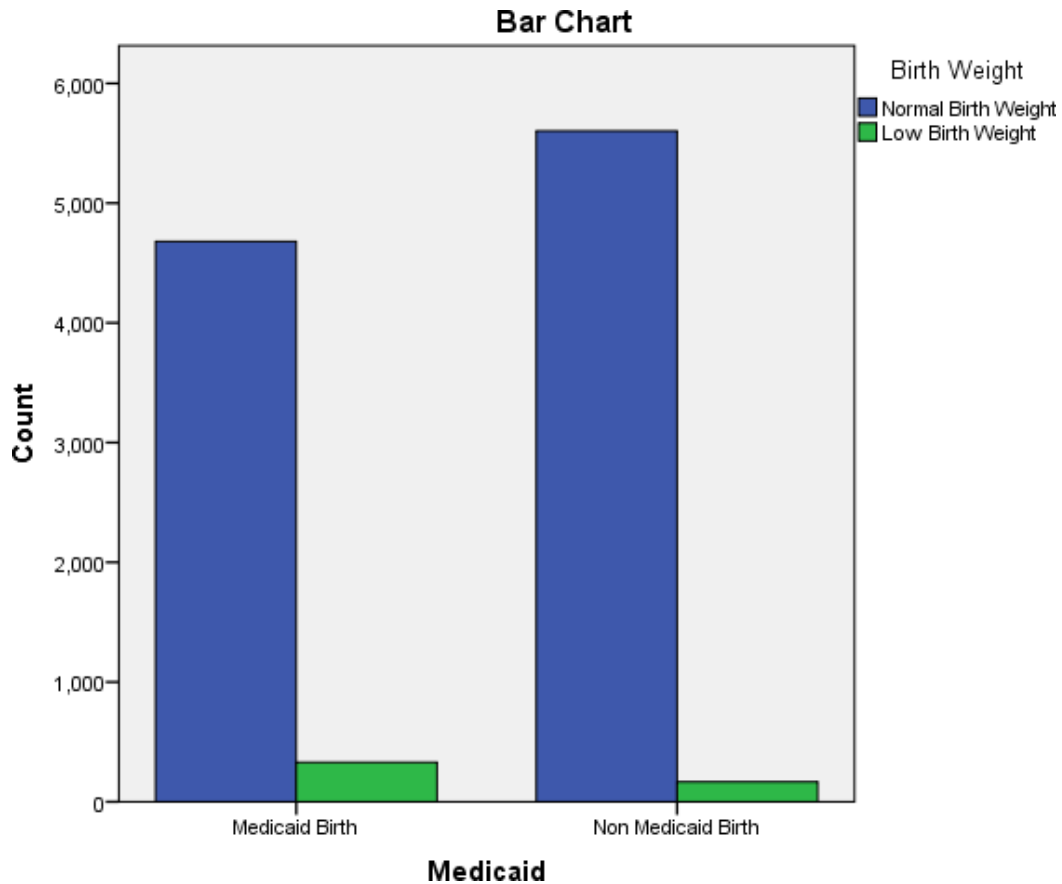


Figure 5. Bar chart of low and normal birth weight with respect to Medicaid and non-Medicaid birth.

From the bar chart (Figure 5), it can be inferred that the total number of delivery for women on Medicaid is 5010 while that of non- Medicaid delivery is 5769. For Medicaid delivery, low birth weight infants was 330 and normal birth weight infant was 4880. Lastly, with regards to non-Medicaid delivery, 167 low birth weight infants and 5602 normal birth weight infants were delivered. Low birth weight infants for women on Medicaid were almost twice as frequent as those of women on other types of insurance.

## Spatial Patterns of Low Birth Weight Incidence on Choropleth Map

The choropleth map shows the spatial distribution or patterns of percent low birth weight cases across the urban-rural gradient of Kalamazoo County from 2008 to 2011. The red areas on the choropleth map indicate hotspot areas or areas that have high incidence of low birth weight cases. The blue areas represent cold spot areas or low incidence areas. However, the pink areas are also regarded as a hot spot areas but with less percentage of cases as compared to the hot spot areas marked in red.

From 2008 to 2011, the minimum and maximum percentage of low birth weight cases in Kalamazoo County was 0% and 40 % respectively. A block group with 0% low birth weight rates is based on two conditions: 1) when there are no low birth weight cases recorded in that particular block group; 2) no birth in that block group. The percentage range of low birth weight cases for hotspot areas is 20.6% and 40% respectively (Figure 6). For this study, percentage low birth weight was computed as the frequency of low birth weight cases per all births (2008-2011) in each block group multiplied by 100% as shown in Figure 6. According to the map, only the central region of the study area had low birth weight cases ranging from 20.6% to 40%. This is evident as the central region is the only portion with red hotspot areas. The central part of the region also showed high spatial clusters of low birth weight cases and this is marked by the pink color (10.1% to 20.5%).

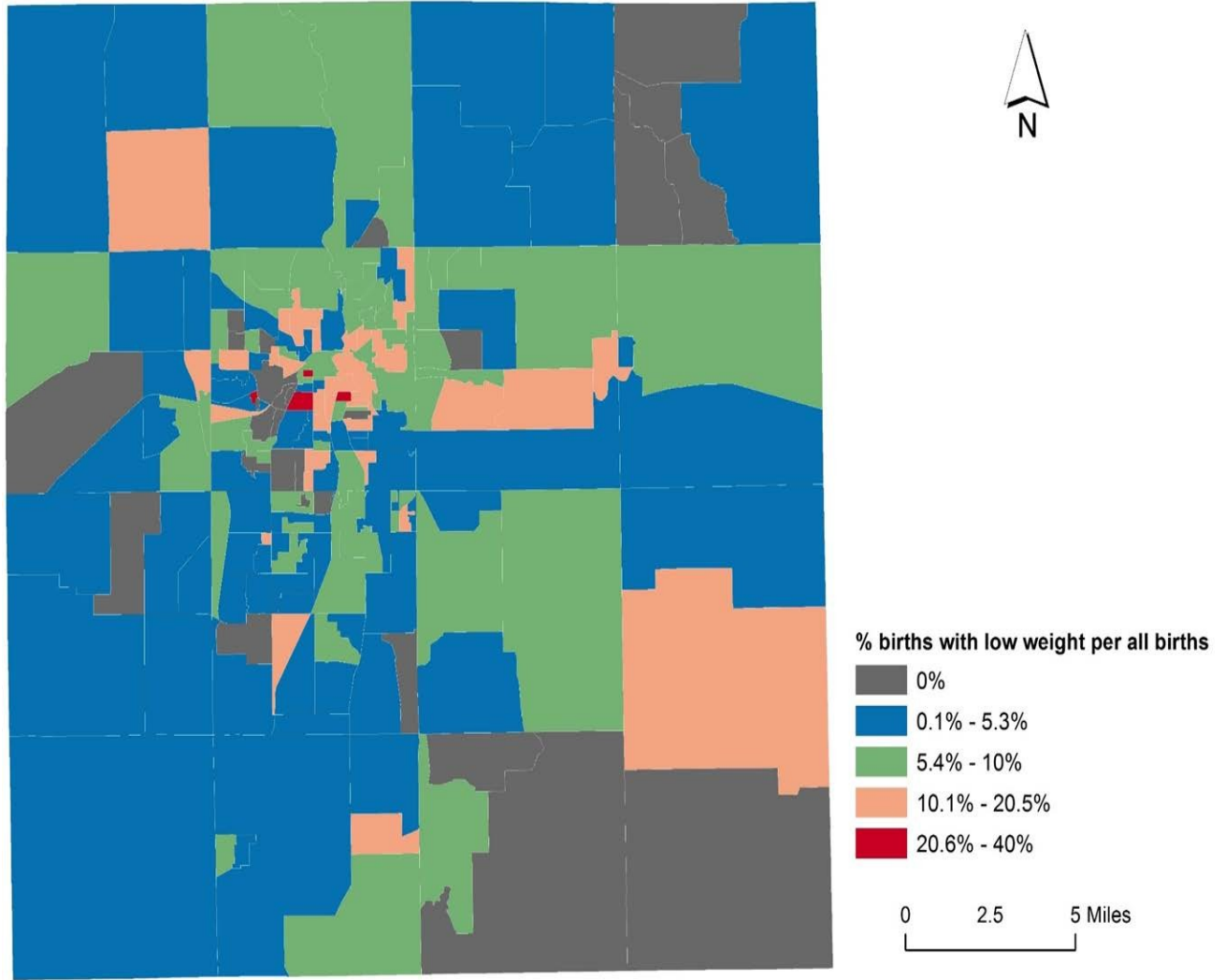


Figure 6. Spatial patterns of low birth weight in Kalamazoo County, from 2008-2011.

According to the map, the central region is the only area that had more hotspot block groups. With respect to block groups that had no cases of low birth weight, the large block groups in the rural townships of Brady, Wakeshma and Ross are particularly prominent on the map. Block groups with low spatial clusters of no cases of low birth weight can be found in Texas, Oshtemo, Portage, Cooper, Kalamazoo city, and Comstock.

The map also shows a high spatial cluster of cold spot areas especially in the southwestern part of the county. Specifically, areas like Prairie Ronde township, Texas township and to a lesser

extent Oshtemo township, show a high spatial cluster for cold spot areas. The city of Portage has high clusters of cold spot areas for low birth weight incidence. Alamo, Richland, and Ross townships each recorded high clusters of low birth weight percentage.

Finally, there is a high spatial cluster of hot spot (10.1% to 20.5%) area located at the eastern part of the county thus, Climax township. However, block groups in Alamo, Comstock, Galesburg, Portage and Schoolcraft also showed hot spot areas (10.1% to 20.5%) but to a lesser extent as compared to Climax township.

### Summary of Low Birth Weight Incidence

Figure 9 shows that, there is high incidence of low birth weight cases in the central parts of the study area. The southwestern part of the study area show high clusters of cold spot areas. Apart from the central part and to a less extent areas where there are outliers of hotspot, a greater percentage of the study area has low birth weight rates from ranging from 5.4% to 10%. High spatial cluster of low birthweight incidence ranging from 10.1% to 20.5% can be found in Climax township and to a less extent Alamo, Comstock, Galesburg, Portage and School craft.

### Spatial Patterns of Socioeconomic Status on Choropleth Map

Socioeconomic status index was derived after running a Principal Component Analysis (PCA) on three variables at the block group level namely; educational attainment (percentage of females 25 and above with less than high school or with high school certificate), median household income, and unemployment (percentage of the population 16 years and above who are unemployed).



Table 10. Pearson correlation matrix for unemployment rate, educational status and median income at the block group level.

	Percentage less than high school	Median Household Income	Percentage Unemployment
Percentage less than high school	1	-0.469	0.506
Median Household Income	-0.469	1	-0.459
Percentage Unemployment	0.506	-0.459	1

Table 11. Component variable show percent of variable that was extracted.

	Component
	1
Percentage less than high school	-0.818
Median household income	-0.791
Percentage Unemployment	0.813

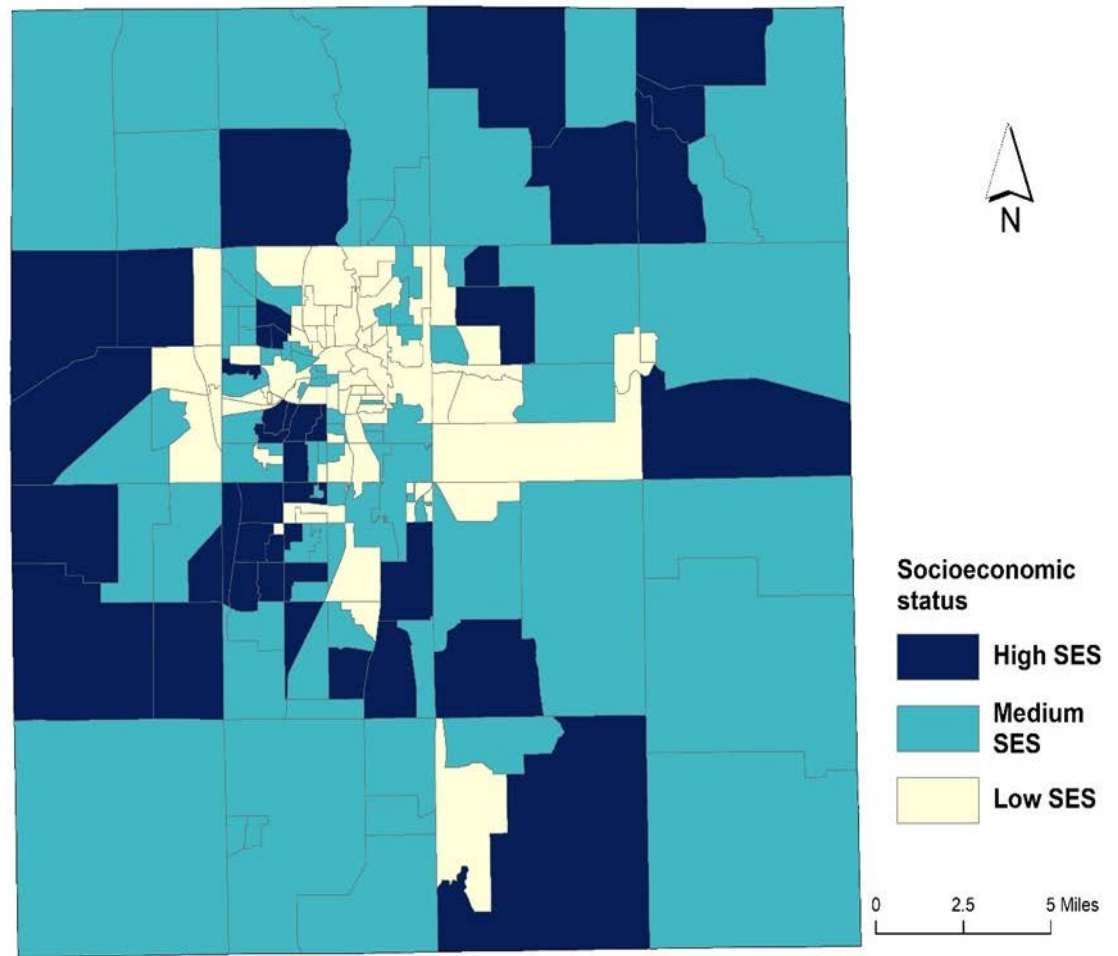


Figure 7. Spatial distribution of socioeconomic status in Kalamazoo County.

The main aim of PCA was to reduce redundancy between variables because they were correlated. Socioeconomic status index at the block group level was categorized into three main groups; thus low, medium and high socioeconomic status after spatially exploring the results (socioeconomic status index) in Geographic Information System (GIS). The minimum, mean, maximum, and standard deviation of SES was used to categorize socioeconomic index low, medium, and high SES. Low SES (-2 to -1.01) was computed as range of values from the minimum to values less than one standard deviation below the mean. Medium SES (-1 to 0.99) was computed

as range of values from one standard deviation below the mean to values to the maximum value less than one standard deviation above the mean. Finally, high SES (1 to 4.1) was calculated as range of values from one SD above the mean to the maximum value. Research has shown that socioeconomic differences in birth outcomes is highly prevalent at the individual or block groups level and also has adverse health behaviors that are socially patterned (Blumenshine, et al., 2010).

According to the socioeconomic status choropleth map, the transparent (white) areas depict block groups in the study areas that have low socioeconomic status. The light blue and dark blue shades represent block groups that have middle class socioeconomic status and high socioeconomic status respectively (Figure 7).

With reference to block groups with low SES, high spatial clustering of block groups at the central region of the study area can be seen to have high rates of low SES. The cities of Kalamazoo and Comstock have high clusters of low socioeconomic status block groups. The western, eastern, and southern regions of Kalamazoo County, thus Oshtemo township, the village of Galesburg, and the city of Portage respectively have low spatial clusters of block groups with low SES. An outlier of low SES can be found at the South region of the County, Schoolcraft (Figure 7).

Although the western area of the map is surrounded by low SES and to a large extent medium SES, a greater portion of the region has high spatial clusters of high SES. The two areas on the map at the western region with high SES are Oshtemo and Texas townships. Portage, a city at the immediate south of Kalamazoo City (central region with high spatial clusters of low SES) also has more block groups with high socioeconomic status (Figure 7). For high SES, there are areas in isolation that have high socio economic status. For example at the extreme south, Schoolcraft has a greater portion of its block group with high SES; also at the North-eastern region, Richland (eastern side of Ross) and Ross both have high SES, Charleston which can be found at the extreme

east of the study area is isolated and to a less extent has high SES. Further Cooper, which is at the north of Kalamazoo city (area with high cluster of low SES), Comstock (east of Kalamazoo city), and Brady (north of extreme south) are to less extent high SES block groups (Figure 7).

According to the map, a greater portion of the study area has medium socioeconomic status. Hence most block groups in Kalamazoo County have medium socioeconomic status. For medium SES, Figure 7 shows that the north, northeastern and southern part of the county have high medium SES.

#### Summary of Socioeconomic Status in Kalamazoo County

According to Figure 7, there is high spatial clustering of low SES at the central sector of the study area, Kalamazoo City; except for the isolated low SES at the south region of Kalamazoo County (Schoolcraft). For high SES, the map shows a high cluster especially at the west of the county. Portage which is located at the south Kalamazoo City (central part with high cluster of low SES), northeast, east and south of Kalamazoo City (central part with high cluster of low SES) (Figure 7). Generally, the choropleth map for SES of the study area shows that most block groups in the study area have medium SES as compared to high and low SES.

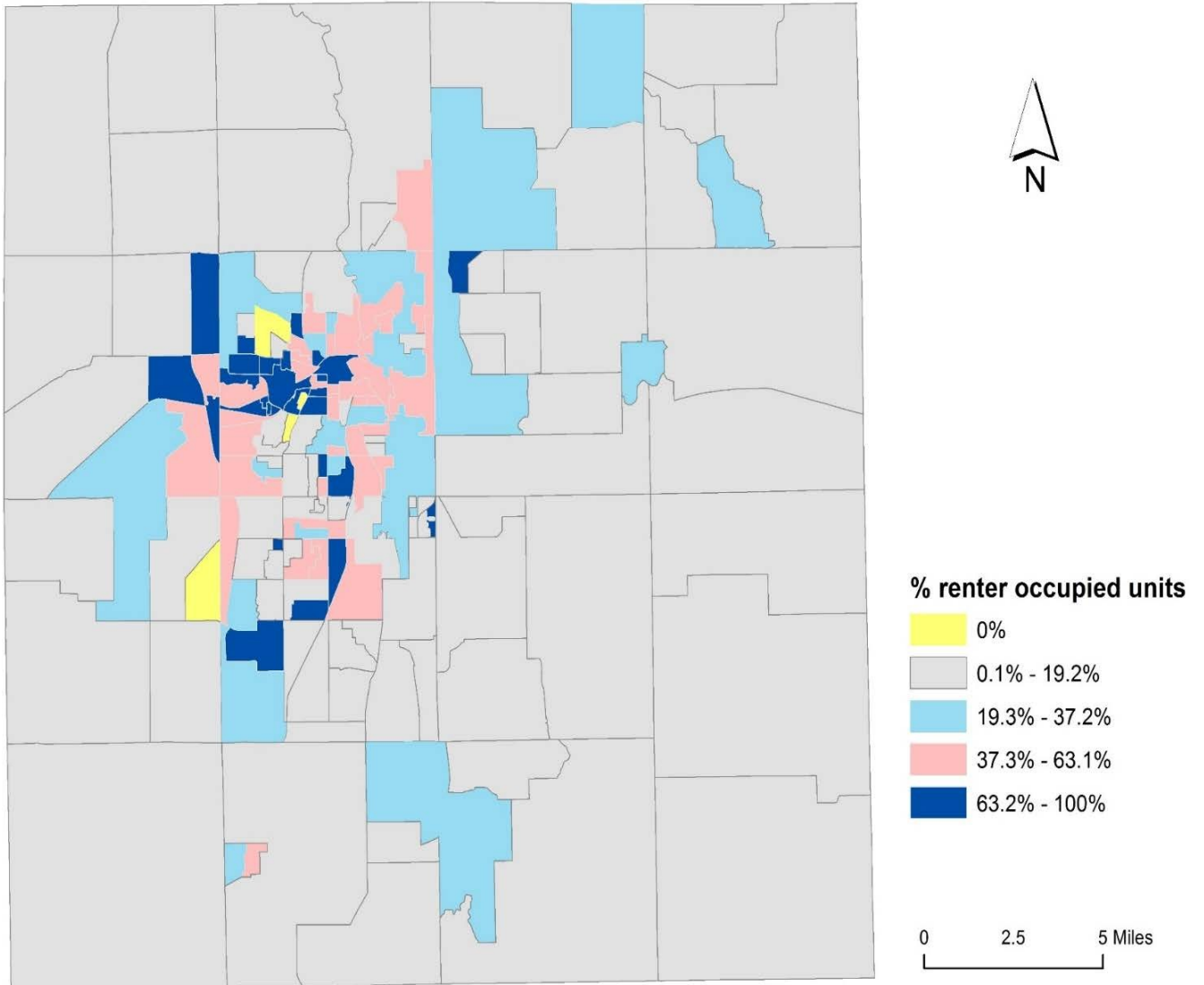


Figure 8. Spatial distribution of renter occupied housing units.

## Spatial Patterns of Renter Occupied Units on Choropleth Map

The map (Figure 8) shows the distribution of renter occupied housing units in Kalamazoo County. The least percentage is 0% while the greatest is 100%. The light yellow shade represent areas where there are no renter occupied units. A critical look at the map reveals that most of the renter occupied units are concentrated in the central part of the study area. The central part of the county is Kalamazoo City. However, it is clear the percentage of renter occupied units in Portage city is less than Kalamazoo city.

For block groups with 0% renter occupied units, the map shows that Kalamazoo city and Portage have few block groups where there is no renter occupied units. The north eastern portion of the county has higher clusters of renter occupied units. The proportion by percentage for these areas range from 37.3% to 63.1%.

Finally, a close look at the map shows that, the range for 19.3% to 37.2% have high spatial clusters as compared to the other groups.

### Summary of Renter Occupied Distribution in Kalamazoo County

Generally across Kalamazoo County, renter occupied units are concentrated in the central region than any other place. The map also reveals that there are more spatial clusters for Kalamazoo city than the rest of study area. Figure 8 shows that a cluster of high rate of renter occupied units in the study area is located at the central part of the study area. As compared to the central region, Portage (immediate south of Kalamazoo City) has low cluster of high rate renter occupied units. For low rate renter occupied housing units, high spatial clusters are located at the southeast, northwest, and southwest.

## Statistical Analysis for Block Group Variables

At the block group level it was hypothesized that low birth weight incidence varies spatially across Kalamazoo County with respect to socioeconomic status, housing types and accessibility. Ordinary least square was used to examine the linear relationship between low birth weight rates and block group variables. Geographically weighted regression was used to explore the spatial relationship between the independent variables and aggregate number of low birth weight cases at the block group level.

Independent variables used are educational level, median household income, unemployment, and transportation accessibility. One assumption of multiple regression is that the independent variables in the model should not have high collinearity. In other words, there should be no multicollinearity between two or more independent variables used (Rogerson, 2015). In order to check for multicollinearity, Pearson correlation was used to examine the correlation between educational level, unemployment, and median household income (Table 10). The key reason for running the principal component analysis (PCA) is to reduce any form of redundancy that exist between the variables that are correlated (Rogerson, 2015).

According to the results (Table 10), at the block group level, there is a high correlation (0.506) between “percent less than high school” and unemployment rate. There was also high correlation between other variables like median household income and unemployment (-0.459), and “percent less than high school” and median household income (-0.469).

One component was extracted based on components with Eigen values greater than 1. The results show that the extracted component can explain about 65.22 % of the variability in the original dataset. The factor loadings of the extracted component shows the relationship between

variables used for the principal component analysis and components (Table 11). A component is a new variable and the loadings are essentially correlation between the old and new variables. The extracted component is added as socioeconomic status in the ordinary least square (OLS) and GWR model.

Table 12. Descriptive statistics of block group level variables (n = 189).

Variable	Minimum	Maximum	Mean	Std. Deviation
Percentage Low birth weight	0	40	6.34	5.78
Percentage of renter occupied units	0	100	30.83	25.28
Percentage of mobile home units	0	92	3.76	11.72
Average number of doctors accessible by bus in 30 minutes	0	4	0.44	0.81
Average number of doctors accessible by bus in 60 minutes	0	7	2.06	1.74
Average number of doctors accessible by car in 15 minutes	0	8	2.08	1.82
Average number of doctors accessible by car in 30 minutes	0	12	6.35	3.42
Socioeconomic status	-2	4.1	0	1.00

#### Descriptive Statistics of Block Group Level Variables

Table 12 shows all the block group variables that were used in the model. In Kalamazoo County, the mean and maximum percentage of low birth weight incidence from 2008 to 2011 is 6.34% and 40% respectively (Table 12). According to the results (Table 12), the average percentage of renter occupied units (30.83%) is about 10 times the average percentage of mobile



home units. For the purposes of this research, accessibility is defined as the average number of doctors that can be reached by bus (30 and 60 minutes) and car (15 and 30 minutes).

Considering accessibility, the mean census block group percentages of doctors (6.35 and 12 for average and maximum number of doctors respectively) can be reached within 30 minutes when using a car. However, the lowest mean census block group percentages of doctors can be reached when using a bus (0.44 and 4 for average and maximum number of doctors respectively). Socioeconomic status which is derived from PCA as explained above, is an index where a high SES is denoted by negative (-) and low SES is denoted by positive (+). Generally in Kalamazoo County, there are more people of medium SES (mean = 0). This is also evident in the geographic pattern of SES (Figure 7).

Table 13. Ordinary least square result.

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	4.347	1.174		3.703	<.0001
Percentage of renter occupied units	0.033	0.018	0.145	1.832	0.069
Percentage of mobile home units	-0.066	0.036	-0.134	-1.835	0.068
Average number of doctors accessible by bus in 30 minutes	-0.286	0.922	-0.023	-0.310	0.757
Average number of doctors accessible by bus in 60 minutes	0.739	1.524	0.057	0.485	0.628
Average number of doctors accessible by car in 15 minutes	2.169	1.475	0.167	1.471	0.143
Average number of doctors accessible by car in 30 minutes	-0.963	1.408	-0.058	-0.683	0.495
Socioeconomic status	2.169	0.471	0.375	4.609	<.0001

All the block group level variables (Table 13) were entered into SPSS and GWR 4.0 software to perform ordinary least square and geographically weighted regression respectively. The output is made up of two models; the Ordinary Least Square (OLS) regression model, and the Geographically Weighted Regression (GWR) model.

The result of the two model is summarized below. The ordinary least square regression is used to examine the linear relationship between the dependent and predictor variables. In the context of this research, the OLS was used to explore the linear relationship between the low birth weight rates (outcome variable) and the independent variables. The estimates represent the size of the regression coefficients for each independent variable. The standard error measures how far the

observed values of the independent variable fall from the regression line. The estimated coefficients was at 5% level of significance.

With respect to low birth weight rates, renter occupied units had a positive correlation and is not significant with low birth weight rates ( $\beta = 0.033, p > 0.05$ ). Mobile home units had a negative correlation with low birth weight rates and not significant with low birth weight ( $\beta = -0.066, p > 0.05$ ).

All transportation accessibility variables were insignificant; average number of doctors accessible by bus in 30 minutes was negatively correlated ( $\beta = -0.286, p > 0.05$ ), average number of doctors accessible by bus in 60 minutes was positively correlated ( $\beta = 0.739, p > 0.05$ ), average number of doctors accessible by car in 15 minutes was positively correlated ( $\beta = 2.169, p > 0.05$ ) and average number of doctors accessible by car in 30 minutes was negatively correlated ( $\beta = -0.963, p > 0.05$ ). .

Socioeconomic status on the other hand is positively correlated and significant with low birth weight rates ( $\beta = 2.169, p < 0.05$ ). This implies that as socioeconomic status of a block group decreases, low birth weight rate also increases.

Table 14. OLS model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.469 <sup>a</sup>	.220	.190	5.2028

Table 14 shows the model summary of the ordinary least square regression model. The R square and standard error of the estimate is 0.220 and 5.2028 respectively. The adjusted R square of the model is 0.19. The value of the adjusted R square is quite low and this implies that 19% of the variability in low birth weight rates is explained by the independent variables at the block group level. The value of the adjusted R square also explains that the relationship between low birth weight rates and block group level variables is weak linear relationship.

Table 15. Diagnostic information for GWR.

Residual sum of Squares	AICC	R Square	Adjusted R Square
4959.60	1178.37	0.21	0.15

The residual sum of squares of the GWR model is 4959.60 and the AICC is 1178.37 (Table 15). The adjusted R square is 0.15 and it implies that 15% of the variability in low birth weight incidence is explained by the independent variables at the block group level. The value of the adjusted R square (0.15) of the GWR is lower than that of the OLS (0.19).

Table 16. Test of geographical variability of coefficients.

Variable	F	Difference of Criterion
Intercept	0.37	0.8
% Renter occupied units	1.64	0.17
% Mobile home units	1.09	0.36
Average number of doctors accessible by bus in 30 minutes	1.86	0.05
Average number of doctors accessible by bus in 60 minutes	0.42	0.52
Average number of doctors accessible by car in 15 minutes	1.01	0.3
Average number of doctors accessible by car in 30 minutes	1.18	0.44
Socioeconomic status	0.33	0.51

Geographically weighted regression is used to explore the spatial relationship between a dependent variable and predictor variables at different locations. Testing the geographical variability of the local coefficients is an ideal way of determining which coefficients vary spatially. In order to determine the spatial variability, use the difference of criterion (Fotheringham et al., 2002, Nakaya et al., 2005). A positive difference of criterion suggest that there is no spatial variability. A positive difference of criterion greater than or equal to 2 suggests that, the local term should assumed to be global (Fotheringham et al., 2002, Nakaya et al., 2005).

Based on the rule of thumb, since the difference of criterion of all the local coefficients is positive, it implies that there is no spatial variability in terms of the local coefficients. Hence low birth weight rates do not vary spatially with block group variables across the urban rural gradient of Kalamazoo County (Table 16). In order to run a GWR test, there should be several hundreds of spatial objects to make it run properly. However, this research does not meet the requirements for the method.

## Independent Sample t- test of Neighborhood Variables

For the purposes of this research, it was hypothesized that low birth weight rates vary spatially with block group variables, or characteristics of an individual mother's 'neighbors'. However, the results of the OLS and GWR model showed that is only a weak linear relationship between the block group level variables and low birth weight rates.

Because the linear relationship was weak, independent sample t-test was used to determine the rates of low birth weight incidence with respect to different thresholds of the block group level variables.

Block group level variables was categorized into low and high levels. In order to categorize into high and low, the minimum, mean, maximum, and standard deviation was used (Table 12). One standard deviation below and above the mean was computed for each variable. The minimum value and all values less than one standard deviation below the mean is considered as low level. Also, range of values from one standard deviation above the mean to the maximum is considered as high level. Finally, all low categories were coded as '0' and low levels were coded as "1" before running the independent sample t –test.

### Results of Independent Sample t-test

Each block group level variable was categorized into two groups; low and high level (Table 17). There are 189 block groups in Kalamazoo County and the sum of the two groups equal to the total number of block groups. The main aim of this test is to examine the rates of low birth weight at different thresholds of the block group level variable.

For renter occupied units, block groups with higher number of renter occupied units had recorded a greater mean for cases of low birth weight as compared to area with low renter occupied

units; 3.10, for high renter occupied units as against 6.81 for low renter occupied units. Renter occupied units is significant with low birth weight rates ( $p < 0.05$ ) and equal variances was not assumed under Levine's test of equality of variance (Table 17).

Moreover, low SES recorded a higher mean for low birth weight incidence than high SES. The mean recorded for low SES (6.81) is double that of high SES (3.1). Socioeconomic status was found to be significant with low birth weight rates ( $p < 0.05$ ) and equal variances were assumed for Levine's test (Table 17).

Mobile home unit was not found to be significant with low birth weight rates ( $p > 0.05$ ). High mobile home units group had less frequency of low birth weight cases (5.60) as compared to low mobile home units (6.69) (Table 17).

All the accessibility variables were not significant with low birth weight incidence and equal variances were assumed for Levine's test. For example accessibility by bus in 30 minutes recorded a mean of 6.071 cases for areas of high accessibility and 6.01 for areas of low accessibility. The case was no different for accessibility by bus in 60 minutes. Block groups of low accessibility recorded low number of cases and vice versa for high accessibility. The mean cases of low accessibility is 4.88 and high accessibility is 6.48. In the case of accessibility by car, both 15 minutes ( $p > 0.05$ ) and 30 minutes ( $p > 0.05$ ) accessibility were not significant with low birth weight rates. The t-test shows that renter occupied units and socioeconomic status has an association with low birth rates and this is consistent with the individual level, where Medicaid is associated with low birth weight rates.

Chi-square test of association showed significant association with maternal characteristics and low birth weight. Independent sample t-test shows the significant association with block group

variables (characteristics of mum's neighbor). OLS and GWR show that, there is a weak linear relationship of LBW and SES.

Table 17. Independent sample t-test for neighborhood level variables.

		N	Mean	Std. Deviation	Levine's test of equality of variance	Sig.
Percentage low birth weight	Low renter occupied units	24	3.10	2.25	Equal variances not assumed	<.0001
	High renter occupied units	165	6.81	5.99		
Percentage low birth weight	Low SES	165	6.81	5.96	Equal variances not assumed	<.0001
	High SES	24	3.10	2.73		
Percentage low birth weight	Low mobile home units	133	6.69	6.16	Equal variances assumed	0.20
	High mobile home units	56	5.50	4.71		
Percentage low birth weight	Low accessibility for Bus in 30 minutes	133	6.01	5.73	Equal variances assumed	0.23
	High accessibility for Bus in 30 minutes	56	7.12	5.89		
Percentage low birth weight	Low accessibility for Bus in 60 minutes	50	4.88	3.73	Equal variances assumed	0.38
	High accessibility for Bus in 60 minutes	139	6.86	6.29		
Percentage low birth weight	Low accessibility for Car in 15 minutes	51	5.06	4.02	Equal variances assumed	0.07
	High accessibility for Car in 15 minutes	138	6.81	6.25		
Percentage low birth weight	Low accessibility for Car in 30 minutes	27	5.07	3.95	Equal variances assumed	0.22
	High accessibility for Car in 30 minutes	162	6.55	6.02		



## CHAPTER V

### DISCUSSION, LIMITATIONS, AND FUTURE RESEARCH STUDIES

The overarching goal of this research study was to investigate and evaluate the spatial variation of low birth weight incidence (2008-2011) with respect to socioeconomic status, housing types and accessibility in Kalamazoo County. In a broader scope, the research study examined the geographic patterns of low birth weight cases and calibrated factors responsible for disparities among different populations considering individual maternal characteristics and block group level characteristics. This research study was conducted at a local scale to plan interventions to reduce disparities in low birth weight in the urban-rural continuum of Kalamazoo County.

#### Summary of Individual and Block Group Level Findings

In Kalamazoo County from 2008 to 2011, the frequency of low birth weight cases for black (235) mothers was a little more than half that of white mothers (420). Although white women recorded a higher number of low birth weight cases, the percentage of low birth weight incidence for black mothers (10.97%) was more than twice that of white mothers (4.66%). This implies that there is high incidence of low birth weight rates in black women than white women. This is consistent with the research findings of Kothari et al., (2016) in Kalamazoo where there is a high rate of low birth weight incidence among black than white women.

Considering age, women in the 20 to 34 years group recorded the highest number of low birth weight cases in Kalamazoo County. However, mothers less than 20 years of age recorded the highest percentage (10.20%) of low birth weight cases. The percentage of low birth weight cases for mothers less than 20 years was more than double the percentages for women in the other age

groups (20-34 years,  $\geq 35$  years) (Table 1). This implies that teenagers have a high chance of delivering infants with low birth weight.

With respect to maternal education, mothers in high school recorded the highest frequency of low birth weight cases (195) (Table 1). Within the four year period, mothers with a less than high school certificate recorded the highest percentage of low birth weight cases (11.47 %). This percentage is about twice the percentage for women in some college or with an associate degree (5.48%) and three times the percentage for women with bachelor's degree or higher. The next highest percentage is for mothers with a high school certificate. This could possibly mean that there is high incidence of low birth weight cases in both women with less than high school certificate and women with high school certificate. However, the two educational groups with low risk of low birth weight babies women in some college or associate degree and women with a bachelor's degree or higher.

Medicaid is a proxy for the socioeconomic status at the individual level. Women on Medicaid insurance are considered to have low income hence low socioeconomic status. Mothers on Medicaid delivery recorded more than twice as much the frequency of low birth weight for mothers on non-Medicaid birth.

At the individual level, it was hypothesized that low birth weight is associated with individual maternal characteristics. Generally the maternal characteristics that were found to be associated with low birth weight are not regarded as causal but only associated with LBW.

The cross tabulation for low birth weight cases and race show that white mothers had less frequency of observed cases for LBW than expected (Table 2). Black mothers on the other hand had more observed frequencies of low birth weight cases than expected frequencies. Also the

expected observed counts for black mothers is almost double the expected counts (Table 3). The results of chi-square test showed that with low birth weight has an association with maternal race. This denotes that a mother's race is a risk factor for low birth weight.

Maternal education was found to be significant with low birth weight cases. The cross tabulation between maternal education and low birth weight cases show that women with less than high school education recorded more counts of low birth weight than expected. The observed counts was twice more than the expected (Table 4). The case was no different for mothers who had completed high school. However, women in the other two categories thus; some college or associate degree and bachelor's degree or higher had lower frequencies of cases than expected frequencies. Again, women with less than high school certificate and women with high school certificate are at a high risk with the former at a higher risk of delivering low birth weight infants. Chi-square result show that a mother's educational level is strongly associated with low birth weight incidence (Table 5).

Teenage mothers or mothers less than 20 years recorded almost twice as much as observed frequency of low birth weight as expected frequency (Table 6). This is reverse for women in the other age groups (20-34 years and  $\geq 35$  years). This could possibly mean that teenagers have high incidence of risk low birth weight babies. Chi-square test shows maternal to be significant with low birth weight (Table 7). Low birth weight has an association with maternal age

Medicaid birth had more frequency of cases than it was expected. Medicaid birth (66.40%) also recorded a higher percentage for low birth weight than non- Medicaid birth (33.60%) (Table 8). As explained earlier, Medicaid is for individuals with low SES. Overall, non- Medicaid birth showed less observed frequency of low birth weight cases than expected frequencies. Table 9

shows that Medicaid is significant with low birth weight. Therefore Medicaid is a maternal risk factor for low birth weight.

The highest percentage of low birth weight incidence in Kalamazoo County from 2008 to 2011 is 40 %. Within this 4 year period, some census block groups recorded neither no births nor low birth weight incidence, hence 0% for low birth weight (Brady, Wakeshma and Ross). According to Figure 6, there are high spatial cluster of hot spot areas (low birth weight incidence) in the central part of the study area. Kalamazoo city is identified as the central region of the study area and it happens to be the only region that has hot spot areas with highest low birth weight cases particularly ranging from 20.6% to 40%. With respect to the 10.1% to 20.5% hot spot areas, a large spatial cluster can be found in Climax township. Also small spatial clusters of this hotspot areas can be found in Portage city, Alamo township, Galesburg township, Comstock township and Schoolcraft township. Generally, large clusters of cold spot areas are found on the southwest and eastern part of the study area (Figure 6).

When visualized, some spatial patterns can be seen with spatial distribution of low birth weight (Figure 6), socioeconomic status (Figure 7) and renter occupied housing units (Figure 8). As discussed above, the central parts of the study area has high incidence of low birth weight. Figure 6 also shows high spatial clusters of low SES in the central region which is Kalamazoo city. Also the northeast part of Portage city is seen to have a small spatial cluster of hot spot area and this is consistent with the north eastern part of Portage City on the SES map. For Comstock township areas with hot spot of low birth weight corresponds with low SES areas in Comstock.

With respect to percentage renter occupied units, some block groups have high percentage of renter occupied units thus percentage ranging from 37.3% to 63.1% and also 63.2% to 100% (Figure 11). These large spatial clusters hot spot areas for renter occupied units are seen to be

predominantly high in the central region of the study area, Kalamazoo city and to a less extent Portage city. This is seen to correspond with the LBW incidence map especially that of Kalamazoo city.

## Discussion

As discussed earlier, analysis in this research study showed that in terms of age, high incidence of low birth weight is prevalent among teenage mothers or young mothers. Study results regarding high incidence of low birth weight in teenage mothers is comparable to previous research by Chen et al., (2007). According to Chen et al., (2007), teenage mothers are associated with increased risk of poor birth outcome such as low birth weight and preterm birth. This is evident that low birth weight has a strong association with maternal age.

Low birth weight has an association with Medicaid status. High incidence of low birth weight is associated with women on Medicaid birth hence low socioeconomic status. It is most likely that women who deliver on Medicaid will have high rates of low birth weight infants as compared non- Medicaid delivery. This finding is consistent with research study Kothari et al., (2016). According to this research studies, low socioeconomic status of women at the individual level is related increased risk of poor birth outcomes such as low birth weight, preterm birth, and mortality.

Low birth weight has an association with maternal race. This research study showed that black women have a high chance of delivering of low birth weight babies as compared to white women. The results show that black women had a double percentage of white women for low birth weight in a predominantly white county. Research studies have shown that black race is a high risk factor of poor birth outcomes in women. Black women have higher odds of delivering low

birth weight infants as compared to white women (Kothari et al., 2016). Racial disparities in birth outcomes have been linked to socioeconomic status. Black women with low socioeconomic status have been found to have high rates of poor birth outcome (Kothari et al., 2016).

Of all the four maternal characteristics used for analysis, maternal education had the highest percentage of low birth weight cases (Table1). Specifically, women with less than high school certificate recorded the highest (11.48%) percentage of cases for maternal education and all maternal characteristic groups including percentage for black women (10.97%). Low birth weight is strongly associated with maternal education with a high risk for women with less than high school certificate.

Considering age, teenagers or women who are less than 20 years recorded the highest percentage (10.20%) for low birth weight incidence as compared to women in the other age categories (20-34 years, 35 years and above). This implies that teenagers are at a higher risk of delivering infants with low birth weight.

At the block group level, low birth weight rate was high in low SES block group, high rental housing block groups. High access block groups via public vehicle to health centers (15 minutes for car) was found to be slightly significant ( $p=0.07$ ). Having high access to health centers could possibly mean that block groups are in close proximity to health centers. There is a high chance of women who have high access via public vehicle to hospitals (15 minutes car) to live in the city of Kalamazoo or Portage. Again Kothari et al., (2016) research study show that low socioeconomic status neighborhood is a risk factor for poor birth outcomes. Hence women living in low SES neighborhoods have high incidence of low birth weight. Therefore, women with low socioeconomic status living in low socioeconomic block groups in the urbanized areas are at a high risk of delivering infants with low birth weight.

## Predicting LBW with OLS and GWR

The OLS model showed that LBW has a weak linear relationship with the independent variables at the block group level. However, only SES was significant with low birth weight at the block group level (Table 13). The GWR model also showed that there is no spatial variability of local coefficients which implies that block group variables do not vary spatially with LBW cases (Table 17). Breaking the block variables into two different groups (low versus high) was able to show the means of low birth weight percentage and whether the difference in means of variables at different thresholds was enough to make it significant with low birth weight. The results of the t- tests showed that block groups with high percentage of renter occupied units have high percentage means of LBW cases. Block groups with a high percentage of low SES have high means of LBW cases (Table 18). Socioeconomic status and renter occupied units are seen to be strongly associated with low birth weight incidence.

At the individual level, all tested maternal characteristics were seen to be associated with low birth weight. Also at the block group level, low birth weight was strongly associated with socioeconomic status and renter occupied units. Individual and community level factors are associated with poor birth outcome. This confirms the findings of Kothari et al. as well as current research in St Louis in Missouri (Kothari et al., 2016, Goldfarb et al., 2018). Some factors were seen to be significant at the individual and block group level. A typical example is Medicaid at the individual level and SES at the block group level.

With respect to this research study, Kalamazoo city is seen to have unusually high spatial cluster of hot spot areas for low birthweight incidence. There is a high chance of these hot spot areas in Kalamazoo city to have high population density of black mothers (Kothari et al., 2016). However, areas like Climax, Schoolcraft, Comstock, Galesburg, and Alamo showed high spatial clusters of LBW even though these areas have a high population density of whites. These areas could be rural areas with low population density and also low educational status. Understanding the scale of problem is essential to placing and structuring intervention strategies. Due to this and other related research the Health Resource and Services Administration (HRSA), an agency of the US Department of Health and Human Services and is responsible for providing and improving healthcare services to individuals who are geographically isolated or medically vulnerable. In the case of Kalamazoo County, the HRSA provides support to pregnant women, mothers, and infants by using the zip code requirements to distribute money and child health in Kalamazoo. For the first time, this program also allows mothers and infants outside of 'poor outcomes' zip codes to be considered for home visiting programs. Hence mothers and infants in high risk neighborhood at the census tract level (in relatively healthy zip codes) will qualify for this program (personal communication with Kathleen Baker, HRSA, 2019).

For specific block groups that have high concentration of low birth weight cases, effective strategies like place-based intervention could help to reduce the burden of LBW amidst low resources counties. For example reaching out to women in such location and providing free healthcare services with the help place based funding initiative.

LBW was found to be significantly associated with mother less than 20 years and young girls in high school or less. Adolescents in schools or young mothers must stay healthy by taking folic acid before or during pregnancy. Furthermore a research study by Aras (Aras, 2013) also



show that teenage mothers have high incidence of low birth weight cases. One effective way to reduce risk of low birth weight prevalence in teenage mothers is by taking folic acid during their pregnancy period. Folic acid is a vitamin B supplement which is essential for development of fetus (Better health, 2019). Pregnant mothers that take folic acid during pregnancy have a reduced risk of low birth weight and small for gestational age (Li et al., 2017).

For Medicaid, getting young women on Medicaid or health insurance before pregnancy is very important. When women of low socioeconomic status wait to obtain Medicaid after pregnancy, there is the likelihood no regular medical checkup before pregnancy. Hence it is possible for any disease affecting them might before pregnancy to deteriorate during their pregnancy stage and affect the growth of the fetus. Also getting Medicaid before pregnancy helps provide information on mother's health record. There should be a policy to ensure that women with low socioeconomic obtain Medicaid before pregnancy stage.

### Limitations

This research study has many limitations. The first limitation has to do with limited variable list. Due to limited variable list and limited available maternal characteristics, especially in the case of Medicaid, it affected the number of years to include in the data for analysis. Also, if data on visiting doctors for prenatal care was available, it would be very ideal to compare low birth weight rates among women based on number of times they have had prenatal care.

The GWR model could not run effectively since several hundreds of spatial objects were required for analysis and this limited the statistical power of the model. LBW rates computation for this research was bias. Many areas of the county have very low population and, thus, very low numbers of births and even fewer low birth weight births. This makes rate calculations in these

census block groups not comparable with areas of higher population density. This is a common problem in most urban-rural counties when analyzing rate data.

This research study only focused on measures of association between two variables but failed to analyze the interactions between three or more variables. For example Medicaid, race and AGE. Chi-square test of association only limits analysis to measures of association between two variables. However, multi- way contingency table allows us examine the interrelationship between more than two variables.

### Future Studies

As discussed above, understanding scale of problem is imperative to target intervention strategies. There needs to be more research on the role of scale of community and pattern of poor birth outcomes to successfully tailor interventions strategy to reduce disparities.

Future studies should also consider adding covariates related to maternal behaviors, like mother smoking and mother drinking during pregnancy and other behaviors. These covariates could help explain better the effects of low birth weight when mothers adapt to these kind of behaviors.

With regards to spatial scale, GWR can run effectively with hundreds of spatial object. As a result future studies should focus on analyzing studies at the regional, state or national level to prevent biasing the results of the GWR.

Whereas this study focused on a small temporal scale, later research should focus on analyzing data at larger temporal scale since this would show effectively the spatial-temporal variations in the study area.

Hotspot analysis should be considered for future research. The hot spot analysis will not only assess high and low values of LBW spatial clusters but also show hotspots of LBW that are statistically significant.

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## APPENDIX A

HSIRB Approval Letter

# WESTERN MICHIGAN UNIVERSITY



Institutional Review Board  
FWA00007042  
IRB00000254

Date: March 8, 2019

To: Kathleen Baker, Principal Investigator  
Gregory Anderson, Co-Principal Investigator  
Eugene Kojo Opore Ahwireng, Student Investigator for thesis  
Collaborators: Amy Curtis, Elizabeth MacQuillan  
Student Investigators: Virginia Dicken, Cara Masselink, Bradley Roberts,  
Bandhan Dutta Ayon

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 15-02-48

This letter will serve as confirmation that the change to your research project titled “Linking Birth Outcomes to Electronic Health Records Data” requested in your memo received March 6, 2019 (to make Eugene Kojo Opore Ahwireng student investigator for thesis) has been approved by the Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

**Approval Termination:**

**March 1, 2020**

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Research Compliance Office  
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