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HEEDING THE PLEA OF THE MUFFLED CRY

(Predicting the Demand for Neonatal Intensive Care Beds in the City of Detroit)

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Steven Dosh

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HEEDING THE PLEA OF THE MUFFLED CRY
(Predicting the Demand for Neonatal Intensive Care Beds in the City of Detroit)

By

Steven Allan Dosh

A THESIS

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ABSTRACT

HEEDING THE PLEA OF THE MUFFLED CRY
(Predicting the Demand for Neonatal Intensive Care Beds in the City of Detroit)

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Infant mortality rates in the United States fell from 20 per 1,000 live births in 1975 to 7.5 per 1,000 live births in 1995. Most of this improvement has been attributed to neonatal intensive care and regionalized perinatal care. Persistently high low-birthweight rates drive the demand for neonatal intensive care unit (NICU) beds, especially among the poor in urban populations in this country. However, this demand for NICU beds is not evenly distributed among neighborhoods in urban populations and there is no current model demonstrating this variation in demand for neonatal intensive care unit beds. In addition, there is no model demonstrating the potential efficiency of inter-facility cooperation among NICUs within a region. The current bed estimates used by health-care planners make no allowance for differences in risks across populations and do not consider the benefits of cooperation among NICUs in a region. Two models are presented in this thesis: A model for predicting the demand for NICU beds and a model demonstrating the effect of varying levels of cooperation among NICUs in a region. These models demonstrate that the demand for NICU beds in a population is closely related to the very low-birthweight of a population and document that inter-facility cooperation can improve system-wide efficiency.

Dedicated to the memory of my father whose love of life, learning, teaching, and the healing arts has been a constant source of encouragement and inspiration in my life.

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A Little Survivor

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LIST OF ABBREVIATIONS

AHA .... American Hospital Association
ALOS .... Average length of stay
DRG .... Diagnostic related group
ELBW .... Extremely low-birthweight
EF .... Etiologic fraction
HPA .... High probability admission
IMR .... Infant mortality rate
IUGR .... Intra-uterine growth retardation
LBW .... Low-birthweight
LPA .... Low probability admission
MHA .... Michigan Hospital Association
MIDB .... Michigan Inpatient Data Bank
NICU .... Neonatal intensive care unit
NINT .... Neonatal intermediate care unit
NMR .... Neonatal mortality rate
PMSA .... Primary metropolitan service area
PTB .... Preterm birth
SIDS .... Sudden infant death syndrome
USPHS .... United States Public Health Service
VLBW .... Very low-birthweight
WHO .... World Health Organization
YPLL .... Years of potential life lost

CHAPTER 1

INTRODUCTION

The rate of deaths among children age one year or less is a major indicator of the health of a country. This is also known as the infant mortality rate (IMR) and it is the number of deaths among babies during the first year of life divided by the number of live births during the same time period (thus it is not a true rate but a ratio). The death rate among infants during the first year of life is higher in the United States than in most other developed nations and is especially high among those who are less privileged in this society. Reducing the national infant mortality rate to seven deaths per 1000 live births by the year 2000 is a goal established by the Surgeon General and the United States Public Health Service.[1] This goal appears to be within reach because the infant mortality rate has fallen steadily from 99.9 per thousand live births in 1915 to 7.5 per thousand live births in 1995, an improvement of 92.5%.[2]

Two basic phenomena have accounted for the improvement in infant mortality rates in this country during the past century: higher standards of living throughout the population and advances in the prevention, diagnosis, and treatment of disease among those who have adequate access to medical care. Better nutrition and higher standards of personal and community hygiene were the dominant forces behind declining infant mortality rates during the first half of this century. Progress in the prevention, diagnosis, and treatment of disease has been responsible for declining infant death rates during the second half of this century.

Advances in the diagnosis and treatment of diseases of newborn babies have been responsible for most of the improvement in survival among infants during the past 25 years in the United States. The infant mortality rate in this country was 20.0 per thousand live births in 1970 and had fallen 62.5% to 7.5 per thousand live births in 1995. The deliberate development of a regionalized system of perinatal care and the development of successful approaches to the management of the sickest and smallest newborn babies have been credited with most of this reduction in deaths among infants in the first year of life.[3] However, the infant mortality rate in the United States is still among the worst of developed countries, ranking 21st in the world in 1995 despite the improvement seen in these rates over the past quarter of a century.[2] Unfavorable infant death rates persist in this country because adverse population-based socioeconomic forces that contribute to infant mortality have not improved during the past 25 years.

Poverty and its social, psychological, and physical consequences affect infant mortality through mechanisms mediated by their effect on birthweight. Social disadvantage is associated with an increased risk of low-birthweight (LBW) that, in turn, increases the risk of death during the first year of life. However, the mechanisms linking poverty and low-birthweight remain obscure and further research is needed to explain the association between socioeconomic factors and birthweight. Nevertheless, the association between social disadvantage, LBW, and infant mortality is clear and steps must be taken to improve the welfare of the poor of this country and minimize the effect of poverty on infant death rates while the association between poverty and infant mortality is explored.

The care provided to sick newborn infants, or neonatal intensive care, as it is commonly known, has blunted the adverse impact of poverty and persistently high LBW rates in this country. However, this has been a two-edged sword yielding improved survival among infants but diverting attention from the underlying socioeconomic determinants of infant mortality. Death rates in the first year of life have fallen and survival has improved even among the smallest and sickest neonates but LBW rates remain high. Although neonatal intensive care has been a dramatic success over the past 25 years, the rate of decline in the IMR has been decreasing steadily since 1980. The benefit of neonatal intensive care may be reaching the point of diminishing returns in light of persistently high LBW rates. In fact, lower death rates among infants may not be possible unless, reminiscent of the first half of this century, the standard of living is improved among socially disadvantaged members of this society.[4]

In the meantime, assuring adequate access to meet the demand for neonatal intensive care is one means of reducing the impact of social disadvantage on infant mortality. Socioeconomic and cultural factors contribute substantially to the demand for intensive care among newborn infants and the supply of neonatal intensive care unit (NICU) beds in a region must be adequate to meet the population-based demand for service. However, there is currently no model available to predict the demand for NICU beds in a population whose gestational age distribution, LBW rate, demographic composition, and socioeconomic characteristics are known. Unfortunately, the current system of regionalized perinatal care makes no allowance for differences in risks across populations, although the demand for neonatal intensive care must be closely related to socioeconomic factors and the LBW rate of a population.

A basic tenet of this thesis is that the population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. National, state, county, or city statistics do not provide enough detail to assess the risk factors responsible for LBW or the detail necessary to determine system-wide effectiveness and efficiency. Measures taken to reduce the population-based demand for NICU services in metropolitan areas will be more efficient and effective if they are guided by an awareness of the location and characteristics of neighborhoods with the greatest need for NICU services. Although the demand for NICU care in suburban and rural populations will not be evaluated in this thesis, it is possible that the methodological approach and models presented here may have applicability to these populations as well.

A valid model is needed for estimating the number of NICU beds required by any given population in light of demographic composition, socioeconomic characteristics, gestational-age distribution, and the LBW rate of the population. This is necessary if access to NICU services is to be assured in the diverse population of the United States during the current era of cost-containment. LBW infants are among the most vulnerable members of society. A model predicting the demand for NICU beds in a geographic region would foster the planning of health-care facilities and would help assure access to critical medical services among those infants who are at greatest risk of death in the first year of life.

The first population-based study of NICU demand in an urban population in the United States is presented in this thesis. It is based on an analysis of neonatal intensive care resource utilization in the city of Detroit between 1984 and 1988. The purpose of this research is to present a model for estimating the number of NICU beds required in our index population in light of current resource utilization rates, demographic and socioeconomic characteristics, gestational age distribution, and birthweight distribution of the population. In addition to providing information on the demand for NICU care in an urban population, this study improves upon the only previous population-based study of the demand for NICU care in the United States because it includes an assessment of the effect of birthweight distribution, gestational age distribution, demographic composition, and socioeconomic characteristics on NICU resource utilization. This is also the first study to demonstrate the distribution of the cost of NICU care within a population, although this study does not improve on the limitations of current NICU cost estimates. The study will also model the potential cost or savings resulting from the institution or withdrawal of interventions with known effects on the birthweight of newborn infants within a population.

The predominantly poor, urban population of Detroit provides an excellent contrast to the predominantly middle class, rural population in the State of Utah, the site of the only previous population-based study of NICU demand in the United States.[5] The socioeconomic and cultural differences between the population of Detroit and the population in Utah are reflected in the differences in the LBW rates in these two populations. Between 1984 and 1988 the LBW rate was 12.7% in the City of Detroit.[6] This LBW rate stands in sharp contrast to the low-birth weight rate of 5.4% in the study population in Utah in 1977. In turn, the differences between the LBW rates of these two populations are reflected in the difference in the demand for NICU beds and emphasize the importance of socioeconomic and demographic factors as determinants of NICU bed demand.

The goals of this study are as follows:

1. Describe neighborhood-specific environmental, demographic, and economic characteristics.
2. Describe neighborhood-specific low-birthweight, very low-birthweight, infant mortality, and neonatal mortality rates.
3. Describe birthweight and gestational age specific infant and neonatal mortality rates.
4. Describe the association between LBW and VLBW and demographic, economic, and environmental neighborhood variables using odds ratios.
5. Describe the association between infant and neonatal mortality and demographic, economic, and environmental neighborhood variables using odds ratios.
6. Estimate the neighborhood-specific demand for NICU beds and cost of NICU care.
7. Compare estimated NICU bed demand with current national recommendations.
8. Develop a model to predict the demand for NICU beds in a population.
9. Model "what if" scenarios for NICU demand and cost encompassing decisions to abstain from resuscitation of extremely LBW infants (< 1,000 grams), variations in system-wide collaboration, and the impact of theoretical changes in the birthweight and gestational age distribution of selected neighborhoods.
10. Model the effect of varying degrees of tolerance for "no bed available" days.
11. Model the effect of NICU size and day-to-day variation in NICU bed demand.

12. Discuss the implications of the descriptive and analytic statistics, the statistical models, and "what if" scenarios.

These goals have been developed as the foundation of the primary hypothesis of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. In addition, these goals will facilitate the evaluation of a secondary hypothesis: The demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population.

In order to reach these goals, the second chapter presents a conceptual framework including fundamental concepts of infant mortality, LBW, NICU care, regionalization of NICU care, and the cost of NICU care. The third chapter reviews the strengths and weaknesses of pertinent medical literature regarding the supply of NICU beds, the cost of NICU care, and the factors affecting the demand for NICU beds within a population. Finally, the methods, results, discussion, and conclusions are presented in chapters four through seven.

Chapter 2

BACKGROUND

The factors affecting the demand for neonatal intensive care are easier to understand and will be more fully appreciated after a review of several fundamental considerations. Therefore, this chapter reviews the following topics:

- The importance of neonatal intensive care
- The risk factors for low-birthweight
- The effectiveness of neonatal intensive care
- The components of neonatal intensive care
- The indications for neonatal intensive care
- Characteristics of infants in neonatal intensive care units
- The location of neonatal intensive care units
- The costs of neonatal intensive care
- The supply of neonatal intensive care beds in the United States
- The forces driving the demand for neonatal intensive care beds
- The primary hypothesis of this thesis

THE IMPORTANCE OF NEONATAL INTENSIVE CARE

Concern for the well being of sick newborns is the obvious justification for neonatal intensive care. However, the need for neonatal intensive care units (NICUs), is related to population-based forces that threaten the health of infants by predisposing to the birth of babies who are born too early and/or too small. These population-based factors are at the core of the social fabric of this country.

INFANT MORTALITY - A SOCIAL MIRROR AND YEARS OF POTENTIAL LIFE LOST

A clear understanding of the causes of death during the first 364 days of life is the key to understanding the importance of NICUs in the United States. These deaths are commonly referred to as infant mortality and represent only a small proportion of deaths in all age groups each year; for example, infant mortality only accounted for 1.3% of all deaths in the United States during 1995. Nevertheless, the infant mortality rate, or IMR, is the focus of much attention.

The IMR is actually a ratio consisting of the number of deaths of infants less than one year of age in a given year as the numerator and the number of live births in the same year as the denominator. This ratio is one of the most widely used general indices of the well being of a country. Deaths among infants under the age of one year are referred to as a "social mirror" because they reflect the existence of socioeconomic inequities that have far reaching effects on the health of a population.[7]

Infant mortality is also important because the years of potential life lost (YPLL) are comparable to other leading causes of mortality in the United States. The YPLL is the sum of the years that a group of people would have lived if they had not died from a given disease or injury before having reached their normal life expectancy.[8] Each infant dying before the age of one loses more than 70 years of potential life. Therefore, as a group, infant deaths contribute substantially to YPLL even though these deaths are only a small portion of all deaths. It is especially important to note that deaths resulting from illnesses or injuries occurring around the time of birth, or perinatal causes, are among the leading causes of YPLL (Table 2.1).

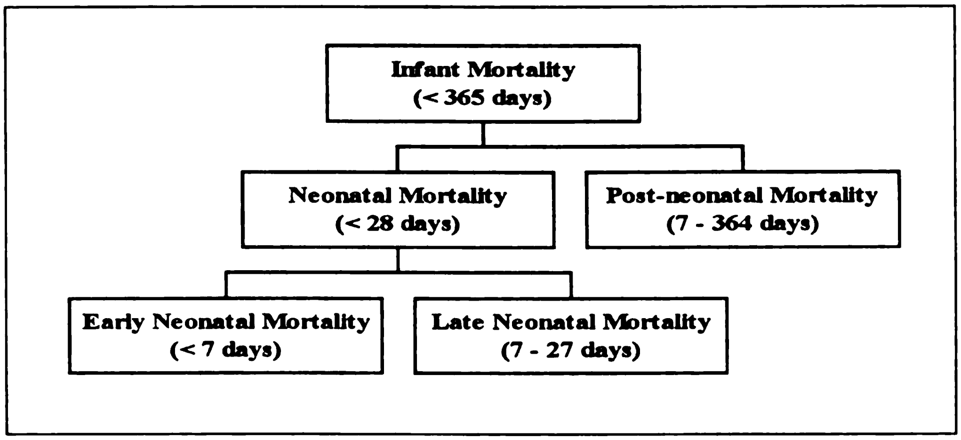
TABLE 2.1
Comparison of Mortality Rates and Potential Years of Life Lost for the Two most Common Causes of and Perinatal Causes of Death in the United States: 1985.
Adapted from McCormick [9]

Disease	Mortality Rate per 100,000 Population	Years of Potential Life Lost
Heart Disease	325.0	1,600,265
Cancer	191.7	1,813,245
Perinatal Causes	10.4	1,453,032

CLASSIFYING INFANT DEATHS

From an epidemiological viewpoint, the biologic mechanisms responsible for death differ depending on the time at which death occurs during the first year of life. Deaths during the first four weeks of life are primarily caused by factors affecting fetal growth and development during pregnancy, or endogenous forces. Most deaths occurring between four weeks and one year of life result from exogenous factors including sudden infant death syndrome (SIDS), infections, and congenital anomalies.[10] Therefore, deaths of infants in the first 364 days of life are categorized according to the age at time of death (Figure 2.1). Neonatal deaths occur during the first 27 days of life while post-neonatal deaths occur from 28 days through 364 days following birth.

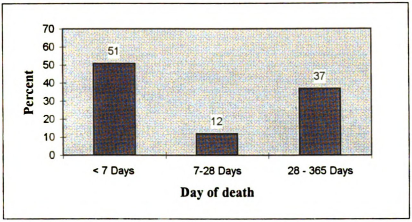
Figure 2.1
Classification of Infant Mortality



The biological mechanisms responsible for death also differ depending on the time of death during the first four weeks of life. Deaths occurring during the first six days of life are usually associated with severe congenital anomalies or extremely low-birthweight (ELBW or birthweight less than 1,000 grams). Many of these deaths, in contrast to deaths occurring between seven days and four weeks of life, are not preventable.[4] Therefore, neonatal deaths are subdivided into early and late neonatal deaths with early neonatal deaths occurring during the first six days of life and late neonatal deaths occurring between seven and 27 days following birth.

The importance of neonatal mortality in the United States is emphasized by the distribution of infant deaths during the first year of life (Figure 2.2).[11] Post-neonatal deaths accounted for only 37% of all infant deaths during 1994, while neonatal deaths accounted for 63%. Upon closer inspection, however, the important role of early neonatal death as a cause of infant mortality is evident because the majority of infant

Figure 2.2
Percent of Infant Deaths by Day of Death



deaths (51%) occur during the first six days of life. Since neonatal intensive care focuses medical resources on the diagnosis, treatment, and prevention of illnesses associated with low-birthweight (LBW), congenital anomalies, and other diseases arising during the first month of life, NICU care plays a vital role in reducing the IMR in the United States.

AN HISTORICAL REVIEW OF INFANT MORTALITY

Although most infant deaths in the United States occur during the first month of life and are associated with LBW, this has not always been true. Infectious diseases were the primary cause of infant mortality in the United States during the first half of this century. The control of infectious diseases through measures such as sanitation, improved community nutrition, vaccination, and antibiotic therapy led to a reduction in such deaths.

As infectious diseases came under control, congenital anomalies and illnesses resulting from LBW and preterm birth (PTB or birth before the start of the 37th week of pregnancy) became, and remain, the most common causes of infant mortality in all industrialized countries (Table 2.2). Disorders directly related to PTB and unspecified LBW accounted for 13% of all infant deaths in 1995. In addition, many deaths due to respiratory distress

Table 2.2
Infant Mortality Rates for the Ten Leading Causes of Infant Death - the United States (1995). Adapted from Guyer [2]

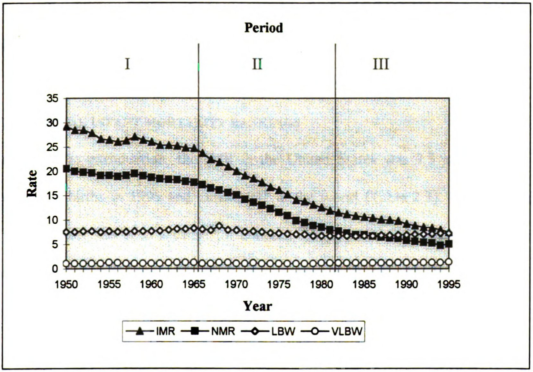
Cause of Death	Percent of All Infant Deaths	IMR
All Causes	100.0	7.5
Congenital Anomalies	22.4	1.7
Disorders Related to Prematurity and unspecified low-birthweight	13.0	1.0
Sudden Infant Death Syndrome	11.2	0.8
Respiratory Distress Syndrome*	5.0	0.4
Newborn Affected by Maternal Complication of Pregnancy	4.2	0.3
Newborn Affected by Complications of placenta, cord, and membranes	3.3	0.3
Accidents and Adverse Effects	2.6	0.2
Infections Specific to the Perinatal Period*	2.6	0.2
Intrauterine Hypoxia and Birth Asphyxia*	1.6	0.2
Pneumonia and Influenza	1.6	0.1

* The actual impact of LBW and PTB is actually greater because preterm birth or low-birthweight often causes these disorders.

and infections specific to the perinatal period are associated with PTB and LBW. Thus, it is clear that reducing infant mortality requires a reduction in infant deaths caused by diseases associated with PTB and LBW.[9]

The role of neonatal intensive care in reducing infant mortality in the United States is emphasized by a review of the historical relationship between birthweight, neonatal mortality, regionalization of perinatal care, and advances in neonatal intensive care (Figure 2.3). Three broad historical time periods can be identified. During period I, the

Figure 2.3
Annual Infant Mortality Rates (per 1000), Neonatal Mortality Rates (per 1000), Low-birthweight Rates (%), and Very Low-birthweight Rates (%) - United States (1950 – 1995)
National Center for Health Statistics [12]



control of infectious diseases, advances in sanitation, and improved community nutrition accounted for the limited reduction in infant mortality between 1950 and the mid 1960s. Between the mid 1960s and the early 1980s, or period II, infant mortality rates in general, and neonatal mortality rates (NMRs) in particular, began to fall rapidly with advances in neonatal intensive care and the deliberate development of a system of regionalized perinatal care that included the introduction of designated NICUs (as will be seen in the next section of this chapter). Finally, in period III the rate of improvement in neonatal mortality rates began to plateau and the limits of contemporary neonatal technology became evident between the early 1980s and the present. As can be seen, the IMR has improved 74% from 29.2 per thousand live births in 1950 to about 7.5 per thousand live births in 1995.[2] The 1995 IMR is close to the goal of 7.0 per thousand live births by the year 2000, which was set by the USPHS.[1] However, these rates remain well above those of many other developed nations.

INTERNATIONAL INFANT MORTALITY RANKINGS

As noted in the introduction, the IMR in the United States was 7.5 infant deaths per thousand live births in 1995 and ranked 21st in the world (Table 2.3). Understandably, this poor ranking has been a cause for concern among health-care planners and policy makers in the United States. However, this ranking must be evaluated in light of the limitations of the data used to generate worldwide infant mortality rankings.

Although efforts are underway to systematize the registration of infant births and deaths and to adopt a uniform definition of a live birth, the absence of this standardization limits the validity of comparisons of infant mortality rates among the countries of the world.[13] The World Health Organization (WHO) has defined a live birth as "the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of pregnancy, which, after such separation, breathes or shows any other evidence of life".[14] While this definition has been adopted throughout most of the United States, it has not been applied universally in other countries. Furthermore, although the reporting of births and deaths is the responsibility of the medical profession

Table 2.3
Infant Mortality Rate per 1000 Live Births in Selected Developed Countries (1992 - 1994)
Adapted from Guyer [2]

Rank	Country	Rate	Year
1	Japan	4.2	1994
2	Singapore	4.3	1994
3	Sweden	4.4	1994
4	Finland	4.7	1994
5	Hong Kong	4.8	1993
6	Norway	5.2	1994
7	Switzerland	5.5	1994
8	Denmark	5.6	1993
9	Ireland	5.9	1994
10	Netherlands	5.9	1994
11	Australia	6.1	1993
12	Austria	6.1	1994
13	France	6.1	1992
14	Germany	6.2	1992
15	Canada	6.2	1994
16	United Kingdom	6.2	1994
17	Italy	6.7	1994
18	New Zealand	7.2	1993
19	Spain	7.2	1994
20	Belgium	7.6	1994
21	**United States**	**8.0**	**1994**
22	Greece	8.3	1994

in this country, in other countries it has been the responsibility of parents to report births, whether live or dead. Theoretically, at least, medical professionals are more consistent in reporting live births and deaths and are better able than parents to identify "any other sign of life".

When comparisons are made between the United States and other developed countries, these differences in definition and reporting affect IMRs because they introduce substantial bias in both the numerator and the denominator of the IMR, as defined earlier.[13],[15],[16] Under current circumstances, the smallest infants are most likely to go unreported in other developed countries. Therefore, the infants who are most likely to die also are most likely to be unreported and this, in turn, introduces a bias which portrays IMRs in the United States unfavorably when compared to other countries with less accurate and less complete reporting of live births. It has even been suggested that differences in registration practices are the primary factor responsible for the poor infant mortality rankings of the United States.[17] Although this may be true, the limitations of international IMR comparisons do not apply to the differences identified when comparisons are made between the IMRs of the socially privileged and the socially disadvantaged in this country.

SOCIOECONOMIC DISADVANTAGE AND INFANT MORTALITY

Crude measures of poverty reveal a disparity between IMRs of the rich and of the poor in this country (Tables 2.4 and 2.5). These differences are concealed in national IMRs. However, the effect of poverty on infant mortality is reflected in the distinct differences between black and white infant mortality in the United States because blacks are disproportionately affected by poverty (Figure 2.4). This is evident when the IMRs for

Table 2.4
Infant Mortality Rates per 1000 Live Births by Maternal Education and Race (1988)[18]

Maternal Education (Years)	Race	
	White	Black
0 – 8	12.5	21.6
9 – 11	12.4	20.0
12	8.1	16.6
13 – 15	6.4	14.7
16 +	5.8	13.3

Table 2.5
Infant Mortality Rates per 1000 Live Births by Family Income and Maternal Race (1988)[18]

Household Income ($)	Race	
	White	Black
< 10,000	11.2	19.3
10,000 - 17,999	9.5	18.5
18,000 - 24,999	7.7	16.1
25,000 - 34,999	7.3	14.6
35,000 +	7.2	16.6

1995 are evaluated more carefully. Among white Americans there were 6.3 infant deaths per thousand live births, while among blacks the rate was 14.9 per thousand live births. Furthermore, between 1970 and 1995 the improvement in the IMR was 64% among whites and 55 % among blacks resulting in a 26% widening of the gap between whites and blacks during those years (Figure 2.5).

The disparity between black and white infant mortality rates is related, in part, to socioeconomic factors, mediated by the effect of these factors on birthweight, and is reduced substantially when adjustments are made for socioeconomic disadvantage. Therefore, a review of the relationship of LBW and infant mortality is expedient.[2]

Figure 2.4
Infant Mortality Rate per 1000 Live Births by Race of Mother: Selected Years (1970 - 1995). Adapted from Guyer (Guyer, Strobino et al. 1996)

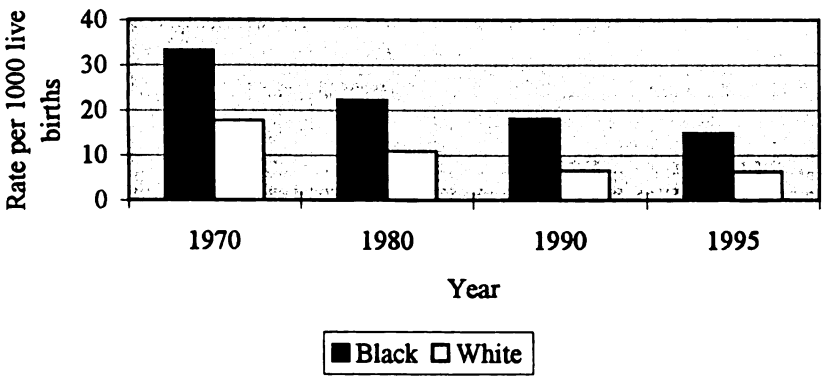
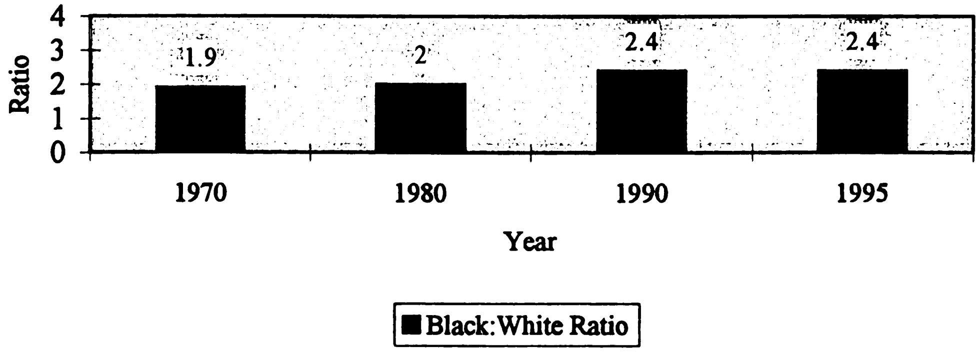


Figure 2.5
Black:White Infant Mortality Ratio
Adapted from Guyer (Guyer, Strobino et al. 1996)

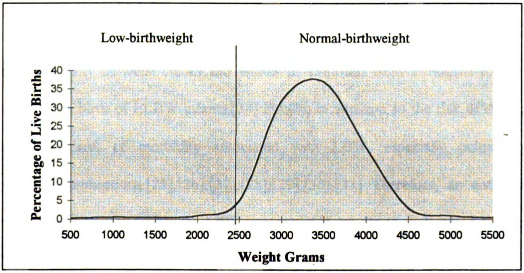


THE RELATIONSHIP BETWEEN INFANT MORTALITY AND LOW-BIRTHWEIGHT

As in most developed countries, the majority of infant deaths in the United States occur in the first few days of life, are associated with diseases related to LBW and congenital malformations, and have their origin before or during the pregnancy (Table 2.2 on page 13).[19],[20] In fact, persistently elevated LBW rates in the United States are believed to be responsible for the higher IMRs in this country when these rates are compared with IMRs in Scandinavian countries.[21] Likewise, most of the discrepancy between IMRs in blacks and whites has been ascribed to the higher LBW rates among blacks.[20] This close relationship between birthweight and infant mortality is best demonstrated by the fact that the very low-birthweight (VLBW) rate of an industrialized country is the best predictor of its neonatal mortality.[22] Therefore, if one is to understand infant mortality, it is necessary to understand the mechanisms responsible for LBW.

By convention, any infant weighing less than 2500 grams at birth is considered LBW (Figure 2.6). Infants weighing less than 1500 grams are considered VLBW and less than

Figure 2.6
Distribution of Birthweights in the United States (1985).[23]



1000 grams are considered extremely low-birthweight (ELBW). In 1995, LBW infants represented 7.3% of all births and VLBW infants represented 1.3% of all births in the United States. Just as there is a disparity between infant mortality in blacks and whites, there is a disparity in the LBW rates between blacks and whites in the United States. In 1995, the LBW rate among whites was 6.2% and was more than twice this rate among blacks (13.0%). In 1994, the VLBW rate was 1.0% in whites and 3.0% in blacks. The disparity remains substantial and, although the LBW rate has fallen slightly for blacks and risen slightly for whites since 1993, the VLBW rates have remained unchanged among black newborns throughout the 1980's and 1990's.[2] These persistently high LBW and VLBW rates in the United States contribute substantially to infant mortality.

LBW infants also have a 40-fold increased risk of neonatal mortality and those who survive carry a heavy burden of morbidity when compared to infants of normal birthweight.[20] VLBW infants accounted for only 1.2% of all births but 64.2% of all neonatal deaths in 1988. This further serves to emphasize the importance of birthweight as a determinant of neonatal mortality. Furthermore, 80% of the racial disparity in neonatal mortality between blacks and whites in 1988 has been attributed to the racial disparity in the birth of ELBW infants.[24] Finally, in addition to the risk of death, there is substantial risk of morbidity associated with LBW, especially pulmonary and neurologic complications.[25],[26],[27],[28],[29],[30],[31] Therefore, an understanding of the mechanisms responsible for LBW is essential if we are to understand the need for NICUs.

The birthweight of an infant is a function of the length of gestation and the rate of fetal growth. The LBW infant may be small because it was born too soon, grew too slowly, or both (Table 2.6). By convention, infants born before 37 weeks of gestation are considered preterm or premature. Any infant whose birthweight is below the tenth percentile for its gestational age is considered small for gestational age and is said to have intrauterine growth retardation (IUGR). It is important to note that not all small infants are preterm and not all preterm infants are small. It should also be noted that many infants who are small for gestational age are otherwise healthy, even though the label "IUGR" suggests the presence of disease. As in most developed countries, the principal cause of LBW in the United States is preterm birth (PTB) but PTB and intrauterine growth retardation both play a role in causing low-birthweight in this country.[32] Therefore, an understanding of LBW requires an awareness of both the factors responsible for PTB and the factors responsible for IUGR.

Table 2.6

Classification of Low-birthweight (< 2500 grams) infants by gestational-age and birthweight for gestational-age. Infants born before the start of the 37th week of gestation are preterm and infants who are below the 10^{th} percentile for their gestational Age have intrauterine growth retardation (IUGR)

	BIRTHWEIGHT FOR GESTATIONAL AGE	
GESTATIONAL AGE IN WEEKS	< 10% (= IUGR)	≥ 10% (= Normal)
< 37 (Preterm)	Preterm with IUGR	Preterm
≥ 37 (Term)	IUGR	Small term

CONCLUSION

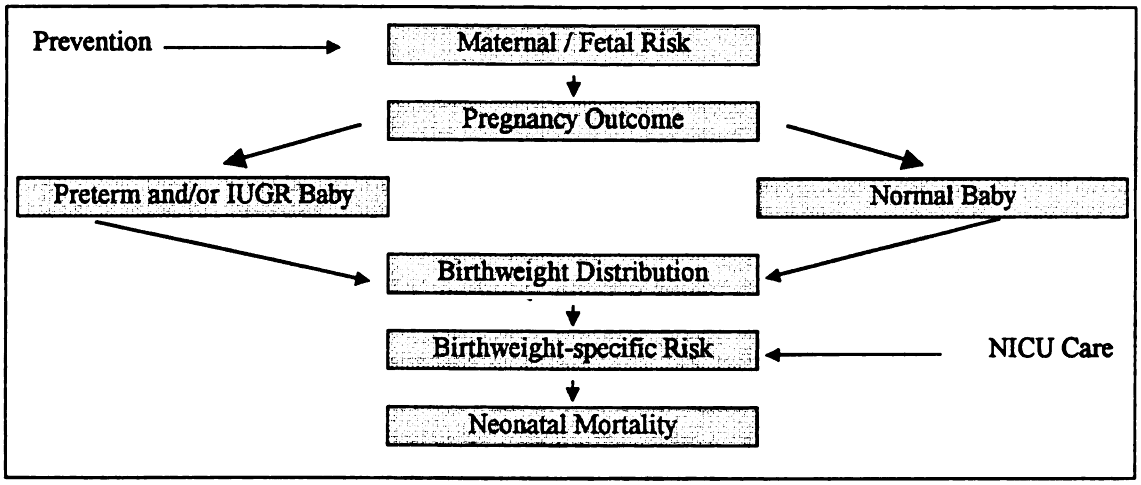
NICUs are necessary in this country because LBW rates are high as a result of too many babies being born too small and/or too early to live without intensive medical care.

THE RISK FACTORS FOR LOW-BIRTHWEIGHT (< 2,500 GRAM)

It should be clear that the causes of LBW begin well before birth. Therefore, it is necessary to identify the risk factors and intervene to prevent LBW or reduce the impact of the risk factors whenever possible. Even when prevention is not possible, arrangements can be made for babies who have a high risk of being LBW to be delivered at regional perinatal centers.

Risk assessment offers the opportunity to identify social, personal, behavioral, and obstetrical factors that contribute to the risks of LBW. Identifying and reducing the risk factors for LBW within a population can both improve the birthweight distribution of the population and facilitate timely access to NICU care (Figure 2.7).

Figure 2.7
The role of risk factor identification in reducing the impact of low-birthweight in a population.



IDENTIFYING RISK FACTORS FOR LOW-BIRTHWEIGHT

LBW has been called "the central biologic mediator of the relationship of social class and economic conditions to infant mortality in industrialized countries".[33] However, the biologic mechanisms linking socioeconomic conditions and LBW remain obscure. The cause of LBW in many infants is multifactorial, many of the potential risk factors are hard to quantify, and there are complex interactions among the potential risk factors. Therefore, identifying risk factors for LBW and establishing the link between socioeconomic disadvantage and LBW has proven difficult. Furthermore, it is necessary to distinguish between the risk factors resulting in LBW due to prematurity and the risk factors for LBW due to IUGR. This adds to the complexity of assessing the important risk factors for LBW. Although determining birthweight is relatively easy, determining gestational age is relatively complex. As a result, it may be difficult to distinguish between the two major categories of LBW: PTB and IUGR. Misclassification, confounding, mediation, and effect modification associated with these characteristics of infants with low-birthweight have often frustrated attempts to identify the determinants of PTB and IUGR.

Studies assessing risk factors for LBW are also fraught with methodological inconsistencies that have further thwarted efforts to establish the biologic link between socioeconomic status and birthweight. The most obvious variation among these studies is the difference in exclusion and inclusion criteria for study samples. The decision to include or exclude infants born before 28 weeks of gestation, infants weighing more than 2500 grams, and infants born during the 37^{th} week of gestation can substantially affect the findings of any given study because the risk factors for infants in each of these categories may differ substantially. Studies of the risk factors for LBW also differ in the definition of exposure. For example, the findings of a study defining alcohol exposure as 2 or more drinks daily may differ from a study defining exposure as one or more drinks daily. These and other methodological differences have contributed to the inconsistency of results among studies of LBW determinants.

Determining the risk factors for LBW has also been hampered by the way the factors have been categorized. Most studies have analyzed LBW, risk, and risk factors as dichotomous or categorical variables rather than continuous variables. This design has been used even though birthweight, risk, and many risk factors exert their influence over a continuum. This approach to study design may make it more difficult to identify the independent effect and the relative importance of most risk factors for LBW. Therefore many of the risk factors for LBW and the relative importance of known risk factors remain undetermined.

Among the potential risk factors associated with LBW are numerous social, personal, behavioral, and obstetrical attributes. Maternal education, marital status, paternal occupation, family income, dwelling size, and number of persons per room are examples of social factors associated with variations in the birthweight of infants. Maternal race, age, height, and pre-pregnancy weight are some of the personal attributes associated with birthweight. Behavioral factors associated with variations in birthweight of infants include maternal alcohol consumption, smoking habits, and nutrition. Obstetrical attributes include parity, weight gain during pregnancy, history of a previous pregnancy resulting in a LBW infant, timing of first prenatal visit, and hypertension induced by pregnancy. This partial listing of suspected risk factors for LBW reveals the potential for misclassification, confounding, mediation, and effect modification emphasized earlier. For example, socioeconomic status affects smoking habits and access to health care while smoking habits affect pre-pregnancy weight and weight gain during pregnancy. Given the risk of confounding and interaction among potential risk factors, it seems clear that multivariate analysis should be a minimum requirement of studies attempting to identify the risk factors for LBW. However, even multivariate analyses have yielded conflicting results.

"KNOWN" RISK FACTORS FOR LOW-BIRTHWEIGHT

Potential risk factors for LBW and the inconsistency of results, even among studies utilizing multivariate analysis, can be demonstrated by a brief review of the results of an extensive meta-analysis, a comparison of risk assessment models, and a study of maternal nutrition and preterm birth (Table 2.7).[34],[35],[36] Each of these studies attempted to overcome many of the limitations of previous studies and, as will be seen, yielded conflicting results. Both the meta-analysis and the comparison of risk assessment models evaluated risk factors for PTB and IUGR independently while the study of maternal nutrition only evaluated the risk factors for PTB. Smoking was identified as a risk factor for PTB in all three studies and low maternal pre-pregnancy weight was also identified as a risk factor in the two studies that evaluated this risk factor for PTB. In addition, maternal height was not found to be a risk factor for PTB in any of the studies. The two studies evaluating the risk factors for IUGR both identified maternal height, maternal

Table 2.7
Comparison of Risk Factors Evaluated and Identified in Three Selected Studies.

Risk Factor	Kramer Meta-analysis	Michielutte Model comparison	Kramer et al Maternal nutrition
Maternal age			
Preterm	-	+	-
IUGR	+	-	N/A
Maternal Height			
Preterm	-	-	-
IUGR	+	+	N/A
Maternal weight (pre-pregnancy)			
Preterm	+	+	N/A
IUGR	+	+	N/A
Maternal race (black)			
Preterm	-	+	N/A
IUGR	+	+	N/A
Single parent			
Preterm	-	-	+
IUGR	-	-	N/A
Maternal education			
Preterm	-	-	+
IUGR	-	+	N/A
No prior live birth			
Preterm	-	+	-
IUGR	+	+	N/A
Smoking			
Preterm	+	+	+
IUGR	+	+	N/A
Alcohol			
Preterm	-	N/A	-
IUGR	+	N/A	N/A
Urinary infection			
Preterm	-	N/A	+
IUGR	-	N/A	N/A
Female infant			
Preterm	-	N/A	N/A
IUGR	+	N/A	N/A

pre-pregnancy weight, maternal race, nulliparity, and smoking as risk factors. Beyond these consistencies among the studies, there is substantial discrepancy in factors analyzed and the results of the studies. These inconsistencies are typical of those found in the existing literature regarding the risk factors for LBW.

The inconsistency in the medical literature regarding risk factors must also be remembered when considering the contribution each risk factor makes to high LBW rates due to IUGR and PTB in the United States (Tables 2.8 and 2.9). The most important

Table 2.8
Risk Factors, Odds Ratios, and Etiologic Fractions for IUGR[34]

Risk Factor	Odds Ratio	Etiologic Fraction
Smoking $\geq$ 11 cigarettes daily	2.42	22.1%
Gestational weight gain < 7 Kg	1.98	13.6%
Maternal pre-pregnancy weight < 49.5 Kg	1.84	11.9%
Female infant	1.19	8.4%
No prior live birth	1.23	7.1%
Prior infant with IUGR	2.75	6.5%
Maternal height < 158 cm	1.27	6.3%
Black race	1.39	6.0%
Alcohol $\geq$ 2 drinks daily	1.78	2.3%

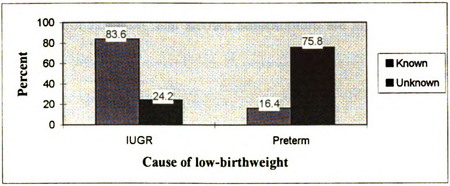
Table 2.9
Risk Factors, Odds Ratios, and Etiologic Fractions for Preterm Birth

Risk Factor	Odds Ratio	Etiologic Fraction
Smoking $\geq$ 11 cigarettes daily	1.41	7.6%
Maternal pre-pregnancy weight < 54.0 Kg	1.25	6.3%
Prior spontaneous abortion	1.57	5.4%
Prior preterm birth	3.08	4.9%

modifiable risk factors for LBW associated with both IUGR and PTB in the United States would appear to be cigarette smoking and maternal nutritional status prior to pregnancy as reflected by pre-pregnancy weight. Improving maternal nutrition before and during pregnancy and eliminating alcohol consumption and cigarette smoking during pregnancy would reduce the risk of IUGR. However, PTB is the most common cause of LBW in this country and most of the risk factors responsible for PTB have not been identified (Figure

2.8). Therefore, most PTBs occur in women who have no identifiable risk factor.

Figure 2.8
Percent of Low-birthweight Infants for whom the Cause is Known for IUGR and Preterm Births. Adapted from Kramer [34]



Identifying the risk factors for LBW associated with PTB is especially important because most LBW in the United States is caused by PTB. Enabling women to avoid cigarette smoking during pregnancy would reduce LBW associated with IUGR at least 22% and PTB at least 8%. Likewise, optimal improvement in maternal nutrition prior to pregnancy would only reduce LBW associated with PTB by a maximum of 6.3%. Finally, it has been suggested that cocaine use during pregnancy may contribute substantially to the PTB rate in this country. However, there has not been a dramatic change in the LBW rates as cocaine use has increased in this country and it is still unclear whether or not cocaine use is an independent risk factor.[37] Since most risk factors for LBW remain to be identified, there is a great need for research to identify the causes of PTB. In the meantime, neonatal intensive care must be available to LBW babies and other sick infants.

CONCLUSION

The etiology of LBW is multifactorial and, for this reason, identifying and quantifying the importance of individual risk factors is difficult. Establishing the biologic link between socioeconomic disadvantage and LBW is especially difficult. However, maternal smoking, poor nutrition, and alcohol consumption are important risk factors in this country.

THE EFFECTIVENESS OF NEONATAL INTENSIVE CARE

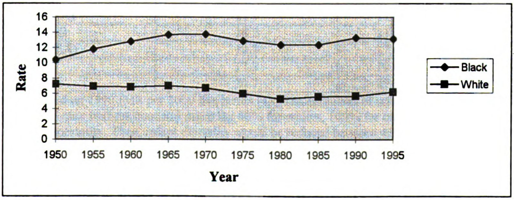
The success of neonatal intensive care in the United States has been dramatic. NMRs in the United States have fallen from 11.6 per thousand in 1975 to 7.5 per thousand in 1995, even though LBW rates have remained relatively constant at about 7% during the same time frame (Figure 2.3 on page 14). The improvement in IMRs has been attributed to a well-planned program of regionalized perinatal care and advances in neonatal intensive care.[38] The fact that LBW infants who receive care in neonatal intensive care units have significantly lower mortality than those who receive care in hospitals without such facilities clearly demonstrates the effectiveness of neonatal intensive care. The relative risk for mortality among LBW infants cared for in other nurseries was about 1.5 when compared to NICUs, although the effect of neonatal intensive care was not uniform across weight groups. It is, however, important to note that the mortality risk among normal-birthweight infants was not lower in hospitals with NICUs.[39],[40], [41]

PERINATAL PARADOX

The improvement in neonatal mortality rates coupled with persistently LBW rates has created what Rosenblatt calls the "perinatal paradox".[42] We have effective treatment for LBW infants but we are unable to identify and correct the factors responsible for high LBW rates. This is demonstrated by evidence that neonatal mortality in the United States is comparable to or better than most other developed countries when the NMR in this country is adjusted for birthweight.[21],[22]

In the absence of effective neonatal intensive care, the IMR in the United States would soar because there has been no change in the population risks during the past 25 years. Furthermore, there has been no change in the gap between the risks of the black and white populations of this country because the socioeconomic determinants of LBW remain essentially unchanged (Figure 2.9). Regionalized neonatal intensive care reduces the impact of failed social policy. Thus, anything that substantially diminishes access to

Figure 2.9
Low-birthweight Rate per Thousand Live Births of Blacks and Whites for Selected Years



NICU services will have a devastating effect on the IMR in the United States. It has been estimated that in 1975 the crude NMR would have been 68% higher for whites and 100% higher for blacks if it had not been for neonatal intensive care.[38] In 1975 the LBW rate among whites was 6.9% percent and among blacks was 12.6%. In 1995 the LBW rate among whites was 6.2% and among blacks was 13.0%. These rates have remained relatively stable during the past 20 years and it seems reasonable to assume that, in the absence of neonatal intensive care, the current NMR would be at least 68% higher among whites and 100% higher among blacks. Since neonatal mortality accounts for 63% of deaths in the first year of life, the IMR in this country would rise precipitously without NICU care (Table 2.10). The consequences of withdrawing NICU services would be greatest among the poor. Thus, continued access to neonatal intensive care is critical, if the impact of the unfavorable birthweight distribution in this country is to be reduced.

Table 2.10

Predicted Infant Mortality Rates in the Absence of Neonatal Intensive Care in the United States and Selected Primary Metropolitan Statistical Area (PMSA), Counties, and Washington, DC*

	With NICU	Without NICU	
		% effect	
Location		**43%**	**68%**
United States	9.2	13.2	15.0
Detroit, MI (PMSA)	11.9	17.0	19.4
Wayne County, MI	16.2	23.2	26.4
Chicago, IL (PMSA)	12.3	17.6	20.0
Cook County, IL	13.3	19.0	21.7
Washington, DC	20.7	29.6	33.7

* This table is based on 1990 IMR per 1000 live births.[43] The estimates of infant mortality without NICU assume that NICU care reduces neonatal mortality 68% for whites, 100% for blacks, and is responsible for 63% of all infant mortality. Thus, infant mortality would be reduced between 43% (.68 * .63) and 63% (1 * .63) depending on the racial mix of the population being studied. This is believed to be a conservative estimate because neonatal intensive care may also reduce deaths after 27 days of life. Note that the impact increases as the geographic resolution increases. By comparison, infant mortality rates in developing countries run in the range of 20 to 120 per 1000 live births.[13]

Conclusion

The regionalized system of perinatal care and advances in neonatal intensive care have played a vital role in reducing the IMR in the face of persistently high LBW rates in this country.

THE COMPONENTS OF NEONATAL INTENSIVE CARE

In a general sense, neonatal intensive care may be defined as any concentrated effort to maintain or improve the well being of an infant who is at risk of becoming ill or who becomes ill before the age of 28 days. As will be elaborated later, there are three basic components of neonatal intensive care: monitoring, testing, and treating the neonate. A newborn infant who is ill or at risk of illness may receive any one or a combination of these components of neonatal intensive care. Such care may be initiated by primary-care physicians in community hospitals in emergency circumstances, but it is usually rendered under the auspices of physicians specifically trained to care for ill newborn infants at regional medical centers with access to highly trained personnel and the latest technological resources.

A review of regionalized NICU care

The evolution of neonatal intensive care in the United States paralleled the technological revolution and the associated specialization that typified the industrial revolution. Systematic efforts to attend to the special needs of newborn infants began to appear before the turn of the current century and have advanced throughout the 20th century. In France during the 1800's, the special needs of mothers and their newborn infants led to the development of hospitals devoted to the care of mothers and their newborn infants. A systematic approach to the care of newborn infants accompanied this innovation in health-care delivery.[9] During the 1920's, Chicago became the site of the first hospital in the United States with a unit for the care of premature infants.[44] Many infants were born at home at that time, so the city of Chicago developed a transport service to facilitate transfer of these infants to the hospital for medical attention and to address the needs of sick neonates who were born at home.[45]

As NICU care became more specialized and technologically advanced, it was clear that limiting the number of hospitals providing NICU service within a given population would both help assure the quality and reduce the cost of NICU care. As a result, the concept of regionalized neonatal intensive care was formulated by the March of Dimes Committee on Perinatal Health in order to promote universal access to specialized perinatal care. This system of care is now utilized throughout this country.[46] Eventually, regionalization of neonatal intensive care services became the mechanism for caring for the needs of sick neonates in the United States.

The goal of regionalized NICU care is to concentrate the care of sick newborn infants from a given region at a hospital capable of providing optimal care to these babies. Ideally, all high-risk newborns would be identified before birth and be delivered in a hospital with a NICU. Since this is not always possible, a secondary goal is to assure that sick neonates are transferred to a NICU as soon as possible after birth. As a result, the success of NICU care in a region can be assessed by determining the proportion of VLBW babies born at the regional center and the proportion of regional early neonatal deaths that occur in a hospital with a NICU.[47] As an example, the state of Michigan is divided into 17 regions (Figure 2.10). Between 1986 and 1988, this state had one of the most effective systems of regionalized NICU care with 76% of all VLBW infants being born at a hospital with a NICU and 68% of early neonatal deaths occurring in regional centers.[48]

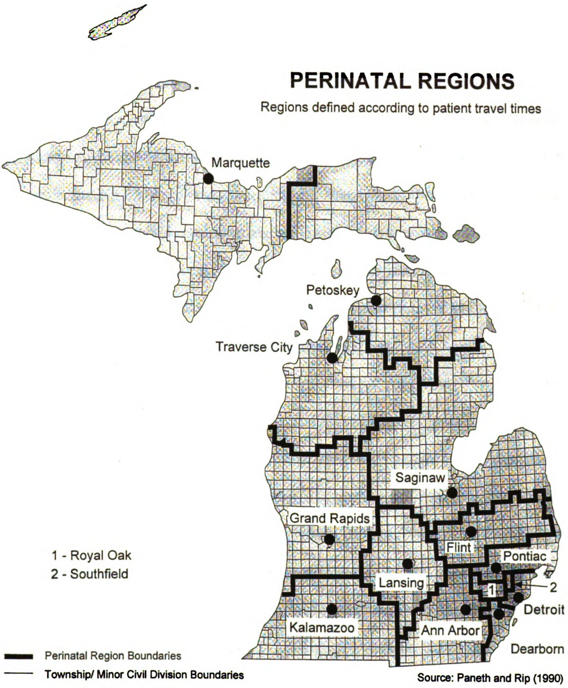
NEONATOLOGY - A NEW SPECIALTY

Special training for physicians who provide care to sick newborns was an integral component of regionalized neonatal intensive care. As a result, neonatology developed as a specialty of pediatrics in response to the special needs of sick newborn infants. In November 1995 neonatology completed its 30th year as an acknowledged subspecialty of pediatrics. The number of NICUs and NICU beds has increased dramatically since neonatology has been recognized as a pediatric specialty. In 1991 there were 712 NICUs, over 11,000 NICU beds, and about 3,000 neonatologists in the United States.[45],[46] This amounts to about 3.9 NICU beds per 1,000 live births and more than 5 neonatologists per 10,000 live births.

TECHNOLOGICAL ADVANCES BUT AT A COST!

The resources a neonatologist brings to bear on the problems of a newborn infant are diverse and expensive. Technologic advances enable the continuous monitoring of the

Figure 2.10
Michigan NICU regions



blood pressure, temperature, pulse, respiration, and oxygenation of the sick infant. Ultrasound technology enhances the ability of physicians to detect infants who are at risk prior to birth and is a non-invasive technology that simplifies the evaluation of selected problems in newborn infants. Advances in respiratory management in the late 1960's and the introduction of surfactant in 1989 resulted in a reduction in the risk of respiratory illnesses associated with PTB.[49],[50],[51] An improved understanding of the nutritional needs of the sick neonate has also facilitated the management of the neonate in the NICU. Articles documenting the effectiveness of neonatal interventions confirmed by randomized clinical trials are catalogued and are being continuously updated.[52] However, the cost of caring for LBW babies is substantial. In 1988 it was estimated that the incremental cost of caring for LBW neonates was $4.0 billion or 35% of the total cost of providing medical care to infants.[53]

CONCLUSION

The essence of neonatal intensive care is an effective, though costly, regionalized, systematic approach to monitoring, evaluating, and treating sick neonates. The origins of this approach to the care of sick newborn infants date back to the late 1800's. The components of neonatal intensive care continue to evolve as our understanding of sick neonates increases, complications of new technology develop, and our ability to care for smaller and sicker newborns increases.

THE INDICATIONS FOR NEONATAL INTENSIVE CARE

There are many clinical situations that prompt a clinician to admit a newborn infant to a neonatal intensive care unit. The most common indications for neonatal intensive care include babies with a birthweight of 1500 grams or less, a gestational age of 32 weeks or less, respiratory distress, sepsis, seizures, persistent hypoglycemia, congenital anomalies requiring diagnostic studies or surgery, and infants of diabetic mothers with serious complications.[46] Ideally, each newborn with one of these conditions would have immediate access to a well-staffed and well-supplied NICU. Clearly, this is not practical given the costs and the difficulty maintaining technical proficiency in facilities doing a low volume of deliveries. These practical limitations were a driving force behind the development of regionalization as a model for delivering neonatal intensive care in the United States. Regionalization controls costs by producing an economy of scale while improving patient outcomes by enabling clinicians and ancillary personnel to maintain competency through an adequate volume of exposure to the common problems encountered in neonatal intensive care units.

TIMELY ACCESS

Although immediate access to NICU care is not practical for every newborn infant, timely access to a NICU with adequate volume to maintain clinical competency is a realistic goal. The importance of adequate patient volume in neonatal intensive care has recently been demonstrated in California.[54] In this study, hospitals with an average NICU census of at least 15 patients per day had lower risk-adjusted neonatal mortality than hospitals with lower average NICU censuses. The odds ratio was 0.62, the 95% confidence interval was 0.47-0.82, and the p-value was 0.002. The importance of timely access to NICU care has also been demonstrated by the fact that LBW infants who are transferred to NICUs after birth have higher mortality rates than those who are born in hospitals with NICU services, although some of this effect may be due to selection bias.[39],[54],[55],[56]

TIMELY TRANSPORT

Ideally, all high-risk deliveries would occur in hospitals with NICUs. Unfortunately, it is not always possible to anticipate the delivery of a sick newborn. Therefore, hospitals providing obstetrical care in the absence of neonatal intensive care must be prepared to stabilize sick newborns and provide rapid transport by qualified personnel to a hospital with a NICU. This is important because failure to transfer LBW infants to NICUs results in higher neonatal mortality.[40], [57] There is, in fact, adequate evidence to suggest that mortality rates are improved for high-risk infants receiving care as early as possible in higher volume NICUs even if this requires transfer at great distances from the hospital where the birth occurred.[41]

CONCLUSION

Whenever possible, high-risk infants should be born in hospitals capable of providing neonatal intensive care. If this is not possible, these infants should be stabilized and transported to a hospital capable of providing NICU services as early as possible. The existence of distance and other barriers limiting access to NICU services have been noted, but these barriers can be overcome to minimize delays in the provision of NICU care.[58]

CHARACTERISTICS OF INFANTS IN NEONATAL INTENSIVE CARE UNITS

The patient mix in a NICU will vary depending on the patient population being served. However, the close relation between LBW and the need for neonatal intensive care makes it possible to identify those newborns that are disproportionately represented in the NICUs of this country. Foremost among those over-represented in NICUs are infants from socially disadvantaged families. In addition, infants of mothers who smoke or drink alcohol, who have had a previous pre-term birth, or who are adolescent are disproportionately represented in the NICUs of this country.[36] It is also important to recognize that black infants are disproportionately represented in NICUs. The racial disparity in NICU occupancy results, at least in part, from the socioeconomic disadvantage of blacks in the United States, as noted earlier. However, most of the infants in NICUs are not in an identifiable high-risk group. Still, the problem of LBW crosses racial lines along a social gradient which favors the socially advantaged through unidentified mechanisms.

LOW-BIRTHWEIGHT

As many as 30% or more of NICU admissions weigh more than 2500 grams and are in the NICU for illnesses unrelated to PTB.[59],[60] Many of these neonates could have avoided NICU admission if intensive monitoring had been available in a different setting. The most common diagnoses in this group of normal-birthweight infants include respiratory disorders other than respiratory distress syndrome, jaundice, and congenital abnormalities. Although normal-birthweight (NBW) infants account for 30% or more of admissions to NICUs, they occupy a smaller portion of NICU beds because LBW newborns have longer average lengths of stay than NBW newborns.[61], [62], [63] In fact, among newborns weighing between 500 and 749 grams at birth and surviving to discharge, the average length of stay is almost 100 days longer than infants of NBW.[62] As a result, LBW infants occupy most NICU beds.

Conclusion

Most NICU attendees are not from an identifiable high-risk group. However, infants born to socially disadvantaged mothers are over-represented in NICUs and most of the babies in NICU beds are there as a result of illnesses associated with PTB and/or IUGR.

THE LOCATION OF NEONATAL INTENSIVE CARE UNITS

Identifying the optimal location for a NICU within a region is necessary to assure access but an ideal location is not sufficient alone to assure access. In addition, the number of beds needed by the population being served must be adequate, patients and referring physicians must understand the importance of NICU care, and there must be an effective system to facilitate pre-natal or early neonatal transfer to the regional center.

MINIMIZING GEOGRAPHIC BARRIERS TO ACCESS

Ideally the location of NICUs would be based on a careful consideration of the location of the populations at risk in order to minimize geographic barriers to NICU care. However, the development of regionalized neonatal intensive care in the United States occurred rapidly and without accounting for differences in risk or demand across populations. In fact, regionalization of neonatal intensive care in the United States occurred so rapidly and was so widespread that by the end of 1979 the effect of a national demonstration program could not be detected because the centralization of neonatal intensive care services had occurred in the comparison areas as rapidly as it had in the demonstration sites.[64] Under these circumstances, the location of NICUs may well have been determined by the location of the population center, at best, and by political and socioeconomic forces, at worst. If the success of regionalization in placing NICUs in effective locations during the 1970's and 1980's could be measured by the concentration of VLBW births in regional centers, the success was quite variable with some centers capturing only a small proportion of high-risk newborns and others capturing the majority of the high-risk population (Table 2.11).[3] Interestingly, several predominantly rural centers were more effective than urban centers in capturing high-risk deliveries. Therefore, the location of NICUs within a region did not necessarily assure access to NICU services because other barriers to NICU access were, and continue to be, important considerations in the current system of regionalization.

The importance of considering population differences when planning regionalized NICU services may be demonstrated by considering LBW rates in the United States. In 1992, the LBW rate in the United States was 7.1% of live births. However, during the same year the LBW rate ranged from 4.9% in Alaska to 14.3% in Washington, DC.[65] A national regionalization plan estimating NICU bed demand from the LBW rate of 7.1% would over-estimate the need for NICU beds in Alaska and underestimate the need in Washington, DC. Between 1991 and 1993, the LBW rate in Michigan was 7.7% with a range of 2.4% for Montmorency County to 11.0% in Wayne County.[6] A state regionalization plan estimating the NICU bed need from the state average would over-estimate the need for NICU beds in Montmorency County and underestimate the need in Wayne County. Therefore, it should be clear that estimating NICU resource demand requires estimating needs using appropriately-sized, populations and addressing distance and other barriers to NICU access as an integral part of such population estimates.

Table 2.11
Concentration of Very Low-birthweight Births in Regional Centers [48]

Region	Year(s)	VLBW %
Ohio	1978 – 79	26
Louisiana	1978 – 79	39
New York City	1983	43
Tennessee	1978 – 79	45
Alabama	1980	56
Iowa	1987	65
Washington	1980- 83	68
Indiana	1987	73
North-central Illinois	1985 – 1986	75
Michigan	1986 –1987	76

CAVEAT EMPTOR

Finally, except in emergency situations, NICU care should only be provided NICUs classified as level-III regional centers. The system of regionalized perinatal care includes specific requirements for formal designation of NICUs, also known as level-III units; intermediate intensive care units, also known as level-II units; and routine newborn care units, also known as level-I units (See Appendix A). However, as far as neonatal mortality is concerned, the benefits of neonatal intensive care have only been demonstrated in designated level-III units. Excess mortality rates have been identified in level-II nurseries and might be avoided if these facilities would, like level I units, transfer LBW infants to level-III nurseries earlier.[40],[54],[55] Therefore, it is best to assume that only level-III units provide NICU care and to recognize this when planning the location of NICUs within a regionalized system or when considering the benefits of neonatal intensive care.

CONCLUSION

The location of NICUs should be guided by the population-based demand for NICU services and the need to minimize the geographic barriers to NICU care.

THE COSTS OF NEONATAL INTENSIVE CARE

The costs associated with NICU care include direct, indirect, and intangible costs. Examples of the direct costs include hospital and physician charges for care of sick newborns in NICUs and the cost of caring for subsequent handicaps in survivors. The time parents of sick newborns lose from work and parental travel expenses associated with travel to and from NICUs are examples of indirect costs. An example of an intangible cost would be the emotional strain experienced by the parents of sick newborns. Ideally, it would be possible to determine the direct, indirect, and intangible costs of NICU care, but in reality this has been difficult, if not impossible to accomplish.

QUANTIFYING INTANGIBLE AND INDIRECT COSTS

The difficulties associated with quantifying the intangible and indirect costs should be relatively clear. For obvious reasons it is difficult to place a dollar value on the emotional stress experienced by parents of a sick newborn infant and it is difficult to establish the indirect costs of NICU care because the data needed to quantify indirect costs is not easily accessible. However, it would seem at first glance that determining the direct costs of NICU care would be relatively easy with hospitals, physicians, and public and private purchasers of medical care having extensive databases that include charge and payment data. Unfortunately, determining the direct cost of NICU care is not easy.

QUANTIFYING DIRECT COSTS

The problems associated with quantifying the direct costs may be less clear. The direct costs of NICU care are difficult to determine due to charges, payments, and costs that are only indirectly and inconsistently related to one another. The reasons underlying the indirect and inconsistent relationship between the charges, payments, and costs of NICU care are found in the system of financing health-care in the United States. The major sources of payment for the NICU care of individual patients in this country include private insurance, Medicaid, other government insurance, and self-pay. In addition to payments made on behalf of individual patients, private grants, public grants, and managed-care contracts also cover some of the costs of NICU care. Although private insurers may pay the billed charges, Medicaid and managed-care contract payments are usually below the billed charges for NICU services and, in fact, Medicaid payments are often substantially below the actual cost of providing NICU care. Health-care providers offset the losses experienced from Medicaid patients and other uncompensated NICU care by cost shifting and cross-subsidization. Cost shifting involves inflating charges to private insurers to cover uncompensated care and losses from Medicaid while cross-subsidization involves inflating charges for lab and other ancillary services to cover these losses. Although cost shifting and cross subsidization facilitates the financing of NICU care, these techniques make it very difficult to determine the actual cost of NICU care in this country.

The inconsistent and indirect relationship between charges, payments, and costs associated with NICU care have also made it difficult to develop a model to predict NICU costs. The Interim Final Rules for Prospective Payments for Medicare Inpatient Services were published in the Federal Register in September of 1983.[66] This method of prospective payment attempted to utilize a system of diagnosis-related-groups (DRGs) to model the length of stay and costs of newborn care. However, as will be seen in the next chapter, this system has been ineffective in predicting the length of stay in a NICU and associated cost of NICU care. Thus, modeling direct NICU costs has also proven difficult.

NICU CARE IS EXPENSIVE

Nonetheless, keeping the limitations of NICU cost data in mind, it is possible to consider the magnitude of the cost of caring for LBW infants. The average cost of caring for a newborn infant weighing 750 - 999 grams was more than 30 times greater than caring for a normal weight infant (≥ 2,500 grams) (Table 2.12). The difference is even more dramatic when only babies who survive to discharge are considered. The average cost of initial hospitalization for LBW infants who survived to be discharged home ranged from $678 for infants ≥ 2500 grams or more to $64,161 for infants weighing 500-750 grams in 1985.[62] This difference is nearly 100-fold.

Table 2.12
Average Length of Stay and Cost of Caring for Newborns from Selected Weight Categories (1988).[62]

Birthweight Category (grams)	Average length of stay (days)		Average cost of care (1985 $)	
	ALL	SURVIVORS	ALL	SURVIVORS
500 – 749	33.4	101.7	22,782	64,161
750 – 999	53.0	76.0	33,206	45,336
1,000 - 1,249	47.7	58.8	24,803	28,486
1,250 - 1,499	35.9	41.7	17,459	19,497
1,500 - 1,999	20.5	22.5	9,157	9,695
2,000 - 2,499	7.5	7.2	2,821	2,568
≥ 2,500	3.5	3.5	718	678
All	5.3	5.0	1,701	1,449

The estimated incremental direct cost for initial hospitalization for each of the 271,000 LBW infants born in 1988 was estimated to be $6,200 or more than $1.68 billion total and the direct incremental costs of caring for LBW infants until they reached the age of 15 was more than $5.5 billion greater than if they had been born NBW.[53] This level of expenditure was comparable to the expense of caring for accidental injuries among children and exceeded the costs of caring for AIDS among Americans in 1988. Clearly, the costs associated with low-birthweight are substantial, especially when direct costs are added to the indirect and intangible costs of NICU care.

CONCLUSION

Although it is difficult to quantify the direct costs and frustrating to quantify the indirect and intangible costs of NICU care, caring for infants who require intensive care is expensive.

THE SUPPLY OF NICU BEDS IN THE UNITED STATES

In 1991 there were 712 NICUs, 386 intermediate intensive care units (NINTs), 11,518 NICU beds, and 4,366 NINT beds. This represents 2.9 NICU beds and 1.1 NINT beds per thousand live births in the United States.[67] Between 1983 and 1991 there was a 46% increase in the number of NICUs, a 67% increase in the number of NICU beds, and a 45% increase in NICU beds per thousand live births while the number of NINTs increased by 74%, NINT beds increased by 71%, and the number of NINTs per thousand live births increased by 49%. During the same time frame, the number of NICU beds per thousand live births increased by 41% in metropolitan areas and by 60% in non-metropolitan areas. The number of NICU and NINT beds combined per thousand live births increased in every region of the United States with the smallest increase being 32% in the East North Central region and the largest increase being 80% in the west south central United States, although the author did not identify the increase in the number of NICU beds per thousand live births by region between 1983 and 1991.

VARIATIONS AMONG POPULATIONS

The number of NICU beds varied between metropolitan and non-metropolitan areas and from region to region in the United States. The number of NICU beds per thousand live births was 3.2 in metropolitan areas and 0.9 in non-metropolitan areas. The number of NICU and NINT beds combined per thousand live births ranged from 2.9 in New England to 4.7 in the west south central United States. Between 1983 and 1991 no region of the United States had fewer than 2.0 NICU and NINT beds combined per thousand live births.

CHILDREN'S HOSPITALS

The preceding NICU and NINT bed counts did not include the NICUs in children's hospitals. NICUs in children's hospitals are unique because they are all located in metropolitan areas, emphasize neonatal surgical care, and do not provide obstetrical services. Therefore, the newborn infants in these NICUs are all "outborn." In 1991 there were 44 children's hospitals in the United States with 1379 NICU beds. This represented a 36% increase in the number of NICU beds in children's hospitals between 1983 and

1991. Adding these beds to the preceding total, there were about 3.0 NICU beds and 1.1 NINT beds per thousand live births in 1991.

GUIDELINES

The *Guidelines for Perinatal Care* recommend one NICU bed per thousand live births and three to four NINT beds per thousand live births.[68] On the surface it would appear that there are too many NICUs and too few NINTs, but hospitals with NICUs also provide NINT service. As a result, the 1.1 NINT beds per thousand live births represent those beds associated with "free-standing" NINT services. Therefore, the current supply of NICU and NINT beds combined is consistent with the recent guidelines.

CONCLUSION

The number of NICU beds varies from region to region and within regions but the total number of NICU beds in the United States is consistent with *Guidelines for Perinatal Care*.

THE FORCES DRIVING THE DEMAND FOR NICU BEDS

Interestingly, there has been very little scientifically sound evidence presented in the medical literature to support a specific recommendation for the number of NICU beds needed per thousand live births. Attempts to determine the demand for NICU beds have been hampered by a number of obstacles. Some of these obstacles are related to regional dif

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differences in health-care delivery, and others are related to regional population differences. The strengths and weaknesses of the medical literature regarding NICU bed demand will be easier to interpret if these obstacles are reviewed first.

SYSTEMATIC DETERMINANTS OF DEMAND

Within the health-care system of a region there are several factors that may lead to variability in the demand for NICU beds. NICUs associated with neonatal surgical services and NICUs with more outborn patients will have greater average lengths of stay and will need more NICU beds.[61] NICUs with liberal admission criteria and conservative discharge criteria will utilize more beds than NICUs with conservative admission criteria and liberal discharge. NICUs used for intermediate or convalescent care will also have greater average lengths of stay and will utilize more beds than NICUs that are not utilized for these purposes. In turn, admission criteria and the utilization of NICU beds for intermediate and convalescent care will be influenced by the availability of other resources within a region. The presence of "free-standing" NINTs within a region may reduce the demand for NICU beds because selected infants may be cared for as well in this environment as in a NICU. Easy access to "free-standing" NINT beds within a region may also allow for the "back transfer" of infants to "free-standing" NINTs, further lowering the demand for NICU beds. The availability of home nursing service within a region may also lower the demand for NICU beds by facilitating earlier discharge of NICU patients during the convalescent phase of an illness. The demand for NICU beds is also affected by other factors in the health-care system including the average daily census of individual NICUs within a region, tolerance for days on which "no beds are available", and the potential for transfer between NICUs when the census of an individual NICU is exceeded for a period of time.

The average daily census of the individual NICUs within a population will affect the NICU bed demand because of a simple, but important, statistical consideration. If the average daily census of a NICU is small, there will be a proportionately greater random variability in the demand for NICU services from day to day because the demand for NICU beds will approximate a Poisson distribution.[69], [70] For example, to meet the total NICU bed demand 97% of the days in a year, one formula for NICU bed demand estimated that a NICU serving a population with 10,000 births annually would need almost 50% more beds per 1,000 births than a NICU serving a population with 63,000 births per year (Table 2.13). Thus, the supply and distribution of NICU beds in a region will need to accommodate this random variability within the population being served.[70]

Table 2.13
Number of NICU beds needed per 1,000 live births to meet the population-based demand 96.7% of the time [70]

Number of Births	NICU Beds per 1,000 births
63,000	0.70
20,000	0.90
15,000	0.93
10,000	1.00
5,000	1.20
1,000	2.00

The tolerance of a health-care system for "no bed available" days in individual NICUs will be inversely related to the number of NICU beds needed by a region. If the goal of individual NICUs in a region is to meet the NICU bed requirements 100% of the days in a

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a year, the number of beds required by a region will be equal to the sum of the maximum number of beds required in each NICU in the region. Freedom to transfer infants between individual NICUs within a region will reduce the number of NICU beds needed by accommodating the census variance of the individual NICUs. For example, during the 1970s and 1980s the New York City infant transport system would determine the appropriate destinations for sick neonates each day based on NICU bed availability within the regional perinatal care system.[71] This system reduced the total number of NICU beds needed and assured access within the system by accommodating day to day variance in the demand on individual NICUs in the region. However, in this era of managed-care, capitation, and reimbursement by diagnostic related groups or DRGs, this type of inter-hospital cooperation is unlikely to flourish. Furthermore, it seems unlikely that the population of the United States will tolerate the limited access generated by "no bed available" days. Finally, demand will be greater in NICUs that have low NMRs in spite of high VLBW rates because the lengths of stay will be greater.

POPULATION-BASED DETERMINANTS OF DEMAND

Although the influence of the health-care system on NICU bed demand is important, the true demand for NICU care is ultimately driven by the needs of the population being served. Thus, the type, number, and location of the NICU beds should meet the real, population-based demand for NICU services within the population. At the same time, the volume of patients in individual NICUs must be high enough to gain from the economies of scale and to enable clinicians to maintain clinical competency. However, because neonatal intensive care is expensive and many of the costs are fixed, it is important that the number of beds does not exceed the demand for NICU services. Therefore, a systematic approach is needed to assure universal, timely, continuous, effective, and efficient access to NICU care. This will only be achieved if the forces driving the demand for NICU beds in a population are understood.

The most obvious population-based factor affecting NICU bed demand is the LBW rate of a population. Among those infants who survive to discharge, the longest average length of hospital stay is in infants who weigh 500 - 749 grams at birth.[62] This weight category has an average length of hospital stay nearly 30 times the stay of normal-birthweight infants (Table 2.14). Most of the excess length of stay among LBW infants is, in turn, spent in the NICU. As a group, LBW newborns account for over one-half of all NICU admissions and these infants have an average length of NICU stay which,

Table 2.14
Average Length of Stay in Hospital by Birthweight Category[62]

	Average length of stay (days)	
Birthweight Category (grams)	**ALL**	**SURVIVORS**
500 – 749	33.4	101.7
750 – 999	53.0	76.0
1,000 – 1,249	47.7	58.8
1,250 –1,499	35.9	41.7
1,500 – 1,999	20.5	22.5
2,000 – 2,499	7.5	7.2
≥ 2,500	3.5	3.5
All	5.3	5.0

depending on the weight category, is 49 – 172 days longer than NBW infants who are admitted to a NICU.[63] Therefore, given the high NICU admission rate and high average length of stay among LBW infants, the LBW rate of a population has a major effect on the demand for NICU beds. Clearly, a population with a higher proportion of VLBW and ELBW infants will have a greater need for NICU beds per thousand live births than a population with a lower proportion of these high-risk newborns.

The PTB rate of a population is another population-based factor that will affect the demand for NICU beds. Newborn infants who are LBW because of PTB have longer lengths of stay than newborns of comparable weight that have LBW because of IUGR.[72] The higher the PTB rate in a population, the greater the number of NICU beds per thousand live births that will be needed by the population. In addition, any factor in a population predisposing to prematurity will affect the demand for NICU care in a population. Thus, the smoking habits, nutritional status, and various other socioeconomic characteristics of a population will affect the demand for NICU through their affect on PTB rates.

CONCLUSION

The demand for NICU beds is driven by conditions within the health-care system and within the population being served. However, LBW rate in general and the VLBW rate in particular is a major determinant of demand for NICU beds in a population.

THE PRIMARY HYPOTHESIS OF THIS THESIS

As a result of the success of neonatal intensive care, LBW newborns now occupy a substantial number of beds in neonatal intensive care units.[73] As noted earlier in this chapter, these infants have longer average lengths of stay and require more intensive care than larger infants.[62, 72] Interestingly, the recommended number of neonatal intensive care beds and the number of staff needed per 1000 live births have remained basically unchanged for the past 25 years.[66, 71] Although the reported number of NICU beds in the United States exceeds the recommended number of beds, these recommendations do not reflect variations in demand across geographic regions, the increased proportion of VLBW infants occupying neonatal intensive care units, or the increased intensity and duration of care needed by the smallest neonates.[45] Furthermore, current estimates of the demand for NICU beds within the system of regionalized care make no allowance for differences in risks for LBW and PTB across populations. Therefore, even if the recommended number of beds may be adequate on a national level, access to neonatal intensive care may be limited in selected regions. This is the foundation of the primary hypothesis of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood.

SUMMARY

The information presented in this chapter demonstrates the important association between NICU bed demand and socioeconomic and cultural factors as mediated by the LBW rate within a population, emphasizes the need to consider the birthweight distribution of a population when determining the number of NICU beds needed within a region, and presents the relative cost generated by each weight category of LBW newborns. This foundation is fundamental to understanding the review and critique of the literature presented in the next chapter and it is the basis for the primary hypothesis of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. In addition, a secondary hypothesis of this thesis is implicit in the evidence presented in this chapter: The demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population.

Chapter 3

LITERATURE REVIEW

This chapter reviews and critiques the relevant published research in the following sequence: Supply, cost, and demand. Published studies about the demand for NICU beds, supply of NICU beds, and cost of NICU care vary in both quantity and quality. The supply of NICU beds and cost of NICU services are briefly considered first. The population-based demand for NICU beds - the primary focus of this thesis - will be presented last.

A Medline literature search of relevant topics for the years 1966-1996 was the initial source of references. Bibliographies contained in these references served to identify related research.

SUPPLY OF NICU BEDS

Surprisingly little has been written about the supply of NICU beds, the distribution of these beds throughout the United States, or the proximity of these beds to the population in need of NICU services. A search of the medical literature during the 30-year period from 1966 through 1996 revealed just one article about the supply of NICU and NINT beds in the United States. This study by Schwartz in 1996 describes the number and distribution of these beds throughout the United States in 1991.[67]

Data obtained from the American Hospital Association's annual hospital surveys for the years 1983, 1987, and 1991 was reviewed. All hospitals affiliated with the American Hospital Association (AHA) with more than five births per year were included in the analysis. These AHA reporting hospitals captured 98% of the births in the United States. Although data from children's hospitals were analyzed separately, the author identified "all" NICUs and NINTs. Schwartz's investigation could be considered a "landmark" article for future comparison because it is the only study of the supply of NICU and NINT beds in this country. It provides an overview of the distribution of NICU and NINT beds among the census sub-regions and between metropolitan and non-metropolitan areas of the United States. The importance of distribution for assuring access to NICU and NINT care was also stressed. Unfortunately, the number of NICUs and NINTs are tabulated without documenting the measures taken to confirm the accuracy of the AHA data. The potential for inaccuracy was demonstrated by the fact that 12.5% of the hospitals reporting NICU beds did not report any NICU bed utilization and were excluded from analysis in the demand portion of the study. Under these circumstances it is not possible to predict the effect this would have had on the results of the study of bed supply. Therefore, these results must be considered crude estimates of the NICU and NINT bed supply. Nonetheless, as noted in the previous chapter, the investigator concluded there were 3.0 NICU beds and 1.1 NINT beds per thousand live births in the United States in 1991.

COST OF NICU CARE

The strengths and weaknesses of the studies of the cost of NICU care will be demonstrated by a review of three representative investigations, and will be limited to these studies of the direct cost associated with initial hospitalization of NICU patients. This approach has been chosen because a review of the indirect and intangible costs is outside the scope of this thesis. In addition, the direct cost of initial hospitalization will only be used as a crude measure to apportion initial NICU cost among neighborhoods for demonstrative purposes.

A study of NICU cost in Florida in 1985 attempted to document the actual costs, charges, and revenues generated by NICU care.[74] Documentation of cost shifting and cross-subsidization was also attempted. The authors used Medicare cost reports to determine direct and indirect *per diem* cost for NICUs. Net revenues by payer were used to assess cost shifting, cross-subsidization was estimated from ancillary charges, and adjustments were made for contractual arrangements. The case-mix was also assessed using DRG codes, surgical status and code, discharge status, birthweight, and ventilator utilization. The average cost per admission for individual hospitals ranged from $922 to $25,225. This study demonstrated the complexity of determining the costs, charges, and payments for NICU care. The descriptive data presented by the authors suggests that cross-subsidization and cost shifting are important means of financing NICU care in indigent populations. Unfortunately, the variation in costs among individual hospitals was great and was not explained by the case-mix of the hospitals. Therefore, the costs presented in this study must be considered crude, conservative, and relative at best.

The Interim Final Rules for Prospective Payments for Medicare Inpatient Services were published in the Federal Register in September of 1983.[66] This method of prospective payment attempted to utilize a system of diagnosis-related-groups (DRGs) to model the length of stay and costs of newborn care. However, this system has been ineffective in predicting the length of stay in a NICU.[61] The DRG system has also been ineffective in predicting NICU cost. In one study, the system of DRGs only explained about 22% of the variation in NICU cost, while a model excluding DRGs but including birthweight, assisted ventilation, surgery, survival, multiple births, and mode of discharge explained 42% of the variation in costs.[59]

In 1989, utilizing a complex formula, Schwartz estimated the average cost of caring for newborns of different birthweights.[62] This formula converted patient charges into estimated average cost by using a charge to cost ratio developed from standardized Medicare Cost Reports that all hospitals are required to report to the Health Care Financing Administration. The data used to generate these estimates were derived from 360 urban NICUs from throughout the United States and included a total of 80,282 births in 1985. Unfortunately, 8,165 infants (10%) were excluded from the study because birthweight data was missing. These infants had a longer average length of stay (12 days vs. five days), had higher average cost ($5,751 vs. $1,449), and were twice as likely to be premature. Therefore, the cost estimates are very likely conservative. Although this method of cost estimation has not been validated, it provides a carefully constructed and standardized approach to estimating cost and for making relative cost comparisons between groups.

DEMAND FOR NICU BEDS

DETERMINANTS OF THE DEMAND FOR NICU BEDS IN A POPULATION

There are three major determinants of NICU demand that are critical if a study of NICU demand is to be generalized to other populations: 1) the population characteristics, 2) the VLBW, LBW, or PTB rate, and 3) the neonatal mortality rate.

First, the demographic and socioeconomic characteristics of a population are closely related to the VLBW, LBW, and PTB rates of the population and should be described in studies of NICU demand. Ideally, these studies would be population-based, but a clear description of the population being served is a minimal criterion. Only two of the studies were population-based.[5],[70] Neither of these described the population characteristics. The remaining five studies were NICU-based. The only study that described the population characteristics was NICU-based.[75]

Second, the VLBW, LBW, and PTB rates of a population must be related to the demand for NICU care and are essential for an accurate determination of the demand for NICU beds in a population. Ideally, estimates of NICU demand would incorporate the VLBW, LBW, or PTB rate of the study population. Interestingly, only one of the studies incorporated the LBW rate when estimating the demand for NICU beds in a region.[5]

Third, the NMR rate of a population must also be related to the demand for NICU care. A population with a high VLBW rate and low NMR will require more NICU beds than a population with low VLBW rate and a high NMR. This is especially important when comparing older studies to contemporary studies because demand has increased as survival among VLBW infants has improved. However, the NMR may be less important when comparing contemporary populations.

In addition to these three critical elements, the demand for NICU beds will be affected by three additional factors: 1) allowance for the size of each NICU in a region and the daily variation in the NICU census, 2) inter-facility cooperation, and 3) tolerance for "no bed available days". These factors may have a substantial effect on NICU bed demand and should be considered. Two studies considered all three of these factors.[70], [69] One study considered two factors: 1) tolerance for "no bed available days" and 2) NICU size and daily variation in census.[75] One study only considered allowance for day to day variation in census.[76]

It is important to remember that the demand for NICU beds in a region is generated by the pattern of NICU utilization. NICU beds occupied by infants who don't require neonatal intensive care or close observation artificially increase the demand for NICU beds. Three studies attempted to assess "real" demand rather than utilization.[5],[70],[76],[77] Evaluating the "real" demand for NICU beds is difficult and would be difficult to incorporate in a model designed to predict the demand for NICU beds. However, the distinction between "real" demand and utilization should be remembered when evaluating studies of NICU demand.

Finally, the presence of neonatal surgical services, the proportion of "outborn" NICU admissions, and the NMR in a region will also affect the demand for NICU beds by affecting the average length of stay. Birthweight-specific lengths of stay will be longer for newborns requiring surgical care and "outborn" infants than for those who don't require surgery or who are not "outborn". These factors are unlikely to have a substantial impact on the demand within a region but may be important when assessing the NICU bed demand of individual hospitals.

PUBLISHED STUDIES AND REPORTS ABOUT NICU BED DEMAND

Unfortunately, there is a paucity of medical literature published regarding the demand for NICU beds. A review of the English medical literature from 1966 through 1996 yielded only seven articles that explored this topic (Table 3.1). Three of these studies were performed in the United States and four in the United Kingdom.

Table 3.1
Published Studies about the Demand for NICU Beds, 1966-1996

Author (Year Published)	Study Country (State or Region)	Study Year(s)	Study Design	Primary Focus
Morriss (1978)	US (Texas)	1978	NICU-based	Daily demand variance
Simpson (1981)	UK (N.E. Thames)	1972, 74, 76	NIUC-based	Clinical necessity of care
Jung (1985)	US (Utah)	1977	Population-based	Clinical necessity of care
Field (1989)	UK (Trent)	1987	Population-based	Clinical necessity of care
Morris (1993)	UK (Northern)	1991	Population-based	Effect of NICU size
Burton (1995)	UK (Trent)	1990-1992	Population-based	Daily demand variance
Schwartz (1996)	US (Inclusive)	1991	Survey	Available "bed days"

Design flaws have limited virtually all of the studies of NICU bed demand to date because they have omitted one or more elements needed to generalize their results to other populations (Table 3.2). Failure to consider these elements has led to great variation in published estimates of the demand for NICU beds in a population (Table 3.3).

Table 3.2
Proposed Standards for Studies Evaluating the Demand for NICU Beds in a Population

Identifies the population characteristics
Incorporates the population preterm birth, low-birthweight or very-low-birthweight rate in any model
Presents the neonatal mortality rate
Allows for daily variation in the NICU census and the effect of NICU size on NICU demand
Considers effect of regional inter-facility cooperation for "back transfer" and "no bed available days"
Discusses Tolerance for "no bed available days"
Uses clinical criteria rather than actual utilization to assess the need for NICU care

In spite of the scarcity and the limitations of the literature about the demand for NICU beds, the *Guidelines for Perinatal Care* recommended one NICU bed, three to four intermediate care beds, and two continuing care beds per thousand live births.[68] This recommendation has remained basically unchanged for the past 25 years. As will be seen, the initial recommendations and subsequently published literature have not established

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Table 3.3
Estimated demand for NICU beds* among "studies" reviewed
ranked from greatest to least total number of NICU and NINT beds recommended

		Beds per 1000 live births		
Author (year published)	**Study Year(s)**	**NICU**	**NINT**	**Total**
Richardson (1976)	1974–1975	1.5	9.3	10.8
Morriss, FH (1978)	1975–1976	1.5	6.3	7.8
Guidelines for Perinatal Care (1992)	Not applicable	1	3-4	4-5
Swyer (1970)	1967–1968	0.7	4.2	4.9
Schwartz (1996)	1991	< 2.9	1.1	< 4.0
Burton (1995)	1990–1992	0.7	2.9	3.6
Morris, DA (1993)	1991	0.6	2.9	3.5
Field (1989)	198.7	1.1	1.5	2.6
Jung (1985)	1977	1.0	1.0	2.0
Simpson (1981)	1972, 1974, 1976	1.3	-	1.3

* Calculated or estimated (if possible) from data when not given by authors

the validity of these recommendations. A review of the seven published studies will demonstrate the limitations of these recommendations. First, two reports are frequently quoted when estimates are made regarding the need for NICU beds in a population. These reports will be reviewed before proceeding to a review of the seven studies of primary interest. Finally, a brief review of the strengths and weaknesses of the current study will be presented after the published literature has been reviewed.

TWO REPORTS ON THE DEMAND FOR NICU BEDS

In the first report, Swyer *et al* described the experience at the Hospital for Sick Children in Toronto, Ontario, to demonstrate the process of planning and organizing a regionalized neonatal intensive care service. The authors provided a formula for estimating the NICU bed requirements of a population.[78] This formula incorporated the expected average length of NICU stay (six days) in the Hospital for Sick Children in Toronto, their regional NICU mortality rate (33%), the number of live births per year in a region of interest, their regional neonatal mortality rate (14%), and an allowance for transitional and con

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convalescent care beds for each NICU bed. One seventh of the beds in this formula were allotted to NICU beds and six sevenths were allotted to transitional beds. For Toronto this was 28 NICU beds (0.7 per thousand live births) and 168 transitional and convalescent (NINT) beds (4.2 per thousand live births).

A simple modification of this formula was later presented in a subsequent report.[79] In the second report, the author suggested that the average length of stay in a NICU should be adjusted to 10 or 11 days based on the occupancy experience of NICUs in California in the early 1970s. This modification led to an estimate of about 1.2 NICU and 7.2 NINT beds per 1,000 live births in a population with a neonatal mortality rate of 14 per thousand live births.

The limitations of the initial formula and its modification should be clear: The population-based elements were limited to the regional live-birth rate and the regional neonatal mortality rate. The NICU in the Hospital for Sick Children cared for two thirds of the infants born in the region and the author did not identify whether or not their experience was representative of other NICUs in the region. The preterm birth rate and low-birthweight rates were not incorporated into the estimates of NICU bed demand, although the regional neonatal mortality rate may indirectly reflect the low-birthweight rate of a population. The average length of stay and the number of beds needed were based on the local utilization experience of the study NICU and not clinical criteria. In addition, the formula has limited usefulness in other populations because it does not consider the following: the beds needed to accommodate the daily variance in NICU adm

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admissions, the tolerance of a system for "no bed available days", or the state of inter-facility cooperation. Therefore, it is unreasonable to apply either of these formulae to other populations.

MORRISS (1978) – QUEUING THEORY AND NICU BED DEMAND

Queuing theory was the basis of another effort to determine the demand for NICU beds.[75] This was a NICU-based study of infants born at a single NICU in Houston, Texas in 1975 and 1976. The authors created a computer simulation model based on their NICU experience. In this model it was assumed (based on regional experience) that 91% of the neonates would be admitted to a low-risk nursery, 5% would be admitted to an intermediate nursery, and 4% would be admitted to a NICU. They then estimated the number of beds that would be needed to achieve a low (5%) probability of "over-census or unavailability of equipment" in each level of newborn nursery. Using this formula the need for NICU beds would be about 1.5 NICU beds per thousand live births. The acknowledgment that NICU admissions are not distributed evenly through the year was important, but the model was based on the average length of stay in a single NICU. The essential elements of this study included a description of population, incorporation of the NMR, allowance for day-to-day variation in NICU admission rates, and tolerance for "no bed available days". Unfortunately, allowance for inter-facility cooperation and the PTB, LBW, or VLBW rates were omitted from the formula. Finally, the NICU bed demand reflected utilization rather than clinical criteria justifying NICU admission.

SIMPSON (1981) - CLINICAL CRITERIA, BIRTHWEIGHT, AND NICU BED DEMAND

A study in 1981 at the London Hospital in Whitechapel determined the NICU admission rate and average length of stay of two NICUs in London, England, and stratified these figures by birthweight.[76] The clinical criteria for NICU care were strict and limited to ventilator support, parenteral nutrition, or an episode of apnea, hypothermia, or pneumonia. These narrow indications for NICU care may have underestimated the actual demand. The proportion of each birthweight group requiring NICU care combined with the average length of NICU stay for each age group was used to estimate the NICU bed demand in the region given the birthweight distribution of the region. The authors suggested that the optimum occupancy rate was 70% to allow for day-to-day variation in the NICU census. Using this formula, the regional demand for NICU beds was estimated to be about 1.3 NICU beds per thousand live births. The demand for NINT beds was not estimated in this study. The stratification of NICU bed demand by birthweight, the attempt to establish clinical criteria for NICU care, and the recognition of the importance of the daily variation in the NICU census were improvements over the previously recommended formulae. However, this study was based on the admission rate and average length of stay of two NICUs, the average length of stay was determined retrospectively from a subgroup of 82 NICU patients, and the authors did not establish whether or not their admission rates and average lengths of stay were representative of the region as a whole. Finally, the authors did not consider the following: population characteristics, inter-facility cooperation, or the tolerance for "no bed available days".

JUNG (1985) – CLINICAL CRITERIA, LOW-BIRTHWEIGHT, AND NICU BED DEMAND

The only population-based study of the demand for NICU beds in the United States was performed in the state of Utah.[5] Jung and Streeter determined the total population NICU bed need from the demand generated by births in the only hospital with a NICU and eight of nine hospitals with intermediate care nurseries during 1977. This group represented the study group. The demand in these units was, in turn, determined using clinical criteria rather than admission rates and average lengths of stay (Table 3.4). Home births and births in one hospital with a level-II nursery and 28 hospitals with Level-I "special care" nurseries were not included in the study. All infants who were transported to the NICU, and 473 of 479 (99%) newborns weighing less than 2,000 grams were "captured" in the study group. The number of larger infants missed by this study could not be determined and the authors assumed that any infants they missed in non-study hospitals would have been larger infants who were minimally ill and would have had short hospital stays. The authors did not consider the following: population characteristics, regional inter-facility cooperation, tolerance for "no bed available days," or the impact of day-to-day variation in NICU bed demand.

Based on the results of this study the authors determined that their population would require 1.0 NICU and 1.0 NINT beds per 1,000 live births. Although all newborn infants were not "captured" in this study and the number of beds needed to meet day-to-day variation in demand for NICU care was not considered, it seems reasonable to assume that the most of the demand for NICU care in Utah was identified. At that time, the low-birthweight rate of Utah was 5.4 per thousand live births and the authors suggested that, using their data as a reference group, the NICU bed demand of a population could be determined. They recommended dividing the low-birthweight rate of a population by 5.4 and multiplying the result by the proportion of each type of bed needed. Thus, if the low-birthweight rate of a population was 8.0%, the NICU and intermediate care bed demand would each be 8.0/5.4 x 1.0 or about 1.5 NICU and 0.7 NINT beds per 1,000 live births. A worked example will clearly demonstrate the practical limitations of this formula.

Table 3.4
Categorization of Infants According to Severity of Illness (Jung 1985)

NICU CARE LEVEL	CLINICAL CRITERIA
Intensive special care	
	All babies with birthweight ≤ 1,500 grams
	All babies of gestational age ≤ 32 weeks
	Respiratory distress
	Stable but requiring ≥ 60% oxygen beyond the first four hours of life
	Unstable or rapidly progressive
	Any infant requiring assisted ventilation
	Sepsis
	Seizures
	Persistent hypoglycemia
	Congenital anomalies (requiring diagnostic studies or surgery)
	Infants of diabetic mothers (if serious complications present)
Intermediate special care	
	Neonates not meeting intensive care with the following:
	All babies with birth weight ≤ 2,000grams
	All babies with gestational age ≤ 34 weeks
	Respiratory distress
	Persisting beyond the first two hours of life
	Requiring oxygen ≥ 40% beyond the first two hours of life
	Suspected sepsis or meningitis
	Meconium aspiration
	Polycythemia
	Infants of diabetic mothers
	Babies requiring exchange transfusions
Minimal special care	
	Neonates who require more hours of nursing care than normal neonates (but don't meet criteria for intermediate or intensive care)
	Infants ≥ 2,001 grams if sick
	Preterm infants ≥ 35 weeks gestation
	Mild respiratory distress requiring < 40% oxygen

During 1988, the low-birthweight rate was about 8.0% in North Carolina. At the time there were approximately 1.5 NICU beds and 1.3 NINT beds per thousand live births. The 11 NICUs in the state had a designation of "no beds available" 75% of the time in 1988. This shortage of NICU beds led to the transfer of some sick newborns out of state for NICU care and some newborn infants stayed in NICUs functioning beyond their capacity. The authors of this study attributed the shortage of beds to high low-birthweight rates and an increased average length of stay due to increased survival rates among extremely low-birthweight newborns.[80] Using clinical criteria, the authors established that during the study 1/3 of the NICU and NINT beds were occupied by intensive care patients, 1/3 by intermediate care patients, and 1/3 by minimal care patients. If the NICU and NINT beds being occupied by minimal care neonates were eliminated from consideration, there would still be about 1.9 NICU and NINT beds per 1,000 live births available to meet the demand for NICU and intermediate care in North Carolina.

The formula proposed by Jung would have estimated the combined NICU and NINT demand at 2.2 beds per 1,000 live births in North Carolina. However, the actual demand exceeded 2.8 beds per 1,000 live births on 75% of the days. The shortcomings of this formula include: a failure to identify the NMR; a failure to recognize the importance of individual NICU sizes in a region and the day-to-day variation in demand; a failure to consider tolerance for "no bed available days;" and a failure to consider the level of collaboration within the health-care system.

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FIELD (1989) – CLINICAL CRITERIA, 70% OCCUPANCY, AND NICU BED DEMAND

A study in the Trent Regional Health Authority of the United Kingdom in 1987 captured 55,750 deliveries (99.9%) in the population.[77] Thus, this can be considered a population-based study of NICU bed demand. Like the study in Utah, these authors used clinical criteria to identify NICU care and its duration but estimated the NINT demand. A goal of 98.9% bed availability (NICU beds available on all but four days per year) within the region was then used to calculate the demand for NICU beds. This yielded an estimated NICU bed demand of 1.1 per thousand live births. Not considered were the following elements: population characteristics, the low-birthweight rate or preterm birth rate, the NMR, inter-facility cooperation, tolerance for "no bed available days", or allowance for the day-to-day variation in NICU bed demand. It should be noted that the study did not present the low-birthweight rate or preterm birth rate for the region but did indicate that 3.3% of the NICU admissions were 1000 grams or less compared to 14% and 13.4% in two large NICUs outside the Trent region. Therefore, this study estimate of NICU bed demand has limited applicability to other populations. In fact, the authors observed that even within the Trent region they had observed considerable variation in the neonatal intensive care workload among various health districts.

MORRIS (1993) - NICU SIZE, VARIANCE IN CASELOAD, AND NICU BED DEMAND

Another population-based study in the Northern Neonatal Network of the United Kingdom evaluated the number of medical NICU beds occupied each day of the year during 1991.[69] The low-birthweight rate for the region was about 6.7%. In this study the demand for NICU care was determined using clinical criteria. The authors estimated the r

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the number of NICU beds needed with the NICUs working collaboratively. They also estimated the number of NICU beds needed if the individual NICUs had functioned independently of one another. The estimated number of NICU beds was 1.0 per thousand live births in a collaborative system and 1.5 NICU beds per thousand live births in a system where the NICUs functioned independently. Unfortunately, the percentage of births actually captured is unclear, although it appears that the study captured the majority of the births. This study did not address the following issues: presence of absence of newborn surgical services, tolerance for "no bed available days", or allowance for day to day variation in demand for NICU care. Finally, the variation in NICU bed demand within the individual health districts of the region could not be determined from this study. Therefore, these estimates would only be applicable to a population with a comparable low-birthweight rate, inter-facility cooperation, and distribution of NICU beds.

Between 1990 and 1992 there was a second study of NICU utilization in the Trent Regional Health Authority of the United Kingdom.[70] This study included a small number of neonates from the region who were cared for outside the region and excluded non-resident neonates who were cared for in the region. Therefore, this study would appear to represent the whole population of interest, but it is not clear what steps were taken to capture all neonates of interest. The demand for NICU care was determined using clinical criteria to identify those infants who needed NICU care and the duration of the NICU care. The clinical criteria for NICU care were very restrictive, namely, required a ventilator or required administration of total parenteral nutrition. This is a very narrow definition of NICU care and probably does not represent the true NICU demand in this population. The authors did consider the effect of the size of individual NICUs within the region and concluded that in a collaborative arrangement 0.43 NICU beds per thousand live births would meet the demand for NICU services. The following elements were not considered in this study: population characteristics, the preterm and low-birthweight rates, tolerance for "no bed available days," and allowance for day-to-day variation in NICU bed demand. These omissions limit the usefulness of this study for estimating NICU bed demand in other populations.

SCHWARTZ (1996) – EXCESS BED-DAYS AVAILABLE AND NICU BED DEMAND

A recent study by Schwartz suggested that in 1991 there were about 300,000 excess NICU bed-days available in the United States.[67] The demand for NICU beds was based on the American Academy of Pediatrics Committee on Fetus and Newborn and Section on Perinatal Pediatrics estimate that about 9% of all newborns require NICU care, the average length of stay is 13.5 days, and the optimal occupancy is 85%.[81] These figures were then applied to the total number of births in the United States by region to estimate the population demand for NICU beds. The study did not contain any of the critical elements needed to determine the demand for NICU beds in a population. In addition the geographic units of evaluation were large and the estimates of NICU admission rates and lengths of stay were crude. Therefore, this study did little to facilitate efforts to estimate the demand for NICU beds.

CURRENT STUDY – FILLING SOME GAPS

As can be seen, virtually all of the studies about NICU bed demand have major limitations. This is especially true when attempting to apply the estimates across populations with differing risk of low-birthweight and preterm birth. The current study is the first step in trying to fill the void in the published literature and reports (Table 3.5)

Table 3.5
Strengths and Weaknesses* of Published Studies of the Demand for NICU Beds

Study	Year	Pop	LBW	NMR	Vary	Co-op	nobed	ClinC
Swyer	1970			■				
Richardson	1976			■				
Morriss, FH	1978	▨	▨	▨	▨		■	
Simpson	1981		▨	▨	▨			■
Jung	1985	▨	▨					■
Field	1989							▨
Morris, DA	1993		▨	▨	■	■		■
Burton	1995	▨		▨	■	■		■
Schwartz	1996							
Current study	1998	■	■	▨	■	■	■	▨

Meets standard ■ Partially meets standard ▨

Criteria legend: Pop = Population identified and population-based. **LBW** = Preterm, low-birthweight, or very low-birthweight rates identified and at least one of these incorporated in the estimation procedure. **NMR** = Neonatal mortality rate identified and considered in the estimation procedure. **Vary** = Allowance for variance in day to day census. **Co-op** = Inter-facility cooperation considered. **nobed** = Tolerance for "no bed days available" considered. **ClinC** = Clinical criteria used to justify admission and length of stay.

CONCLUSION

Overall, the estimates of demand for NICU beds range from 0.5 to < 2.9 per 1,000 live births and for NINT beds range from 0.5 to 7.2 per 1,000 live births (Table 3.3). Clearly, further research is needed to establish a valid method of estimating the NICU bed demand of a population given the low-birthweight rate, preterm-birth rate, availability and utilization of intermediate care nurseries, the number of NICU beds in the individual NICUs of a region, the status of collaborative health-care delivery in the region, the presence or absence of neonatal surgical services within a region, and the distribution of the demand within a region.

SUMMARY

The previous chapter presented the background necessary to understanding the factors affecting the demand for neonatal intensive care services. This chapter has presented a review and critique of the relevant published research in the following sequence: Supply, cost, and demand. The strengths and weaknesses of the research are evident.

The study that will be presented in the following chapters fills a void in the available literature by assessing the demand for NICU beds in light of factors known to have an impact on NICU bed demand. The variation in demand among different populations should be evident from the literature review and is the basis of the primary hypothesis of this study: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. In addition, the literature review also suggests that the LBW rate of a population may be a determinant of NICU bed demand and supports the secondary hypothesis of this thesis: The demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population. The next chapter will present the methods used to reach the goals presented in the introduction of this thesis and test the hypotheses of this thesis.

CHAPTER 4

METHODS

This chapter describes the study methods. First, an overview of the study, the geographic area of interest, and the procedure used to link the databases is presented. Next, the methods used to estimate NICU demand and cost is described. Finally, the methodological approach to modeling, statistical analyses, statistical significance, ecological fallacy, and validation of the database and models are discussed.

OVERVIEW

This is a population-based descriptive study of the NICU bed demand generated by all infants born to mothers residing in the City of Detroit, Michigan, between 1984 and 1988. A database identifying the characteristics of the individual infants and the mother's neighborhood of residence at time of birth was created by linking geocoded birth certificates, death certificates, and 1990 census tract data. Infant data were grouped by neighborhood because these areas are more homogenous than the City of Detroit as a whole and city planning is often done at this level. A rational method of estimating neighborhood-specific NICU demand was developed to demonstrate the variation in NICU bed demand among individual neighborhoods within Detroit. The purpose of this study, as approved by the Michigan State University Committee on Research Involving Human Subjects (UCRIHS), was to develop a model from these data to predict the demand for NICU beds in other urban populations.

The sources of the data used in this study included vital records from the Michigan Department of Community Health, 1990 census tract data, and national birthweight-specific length of stay and cost for newborn infants in urban populations. This data was used to estimate the primary outcome of interest: neighborhood-specific NICU bed demand per 1,000 live births per year. The mathematical relation between neighborhood-specific demand and VLBW rate is described in a linear regression model. The neighborhood-specific relative cost of NICU care, a secondary outcome, was also estimated from the data and the relationship between neighborhood-specific cost and VLBW is described in a linear regression model.

GEOGRAPHIC AREA OF INTEREST

The geographic area of interest is the City of Detroit. This city is located in the southeastern corner of Michigan within Wayne County (Figure 4.1). Detroit consists of 321 census tracts (1990), that the United Community Services (UCS) of Metropolitan Detroit organized into 47 sub-communities (neighborhoods) in 1990 (Figure 4.2). Approximately 4,000 people reside in each of these neighborhoods.

Figure 4.1
Michigan with Wayne County highlighted

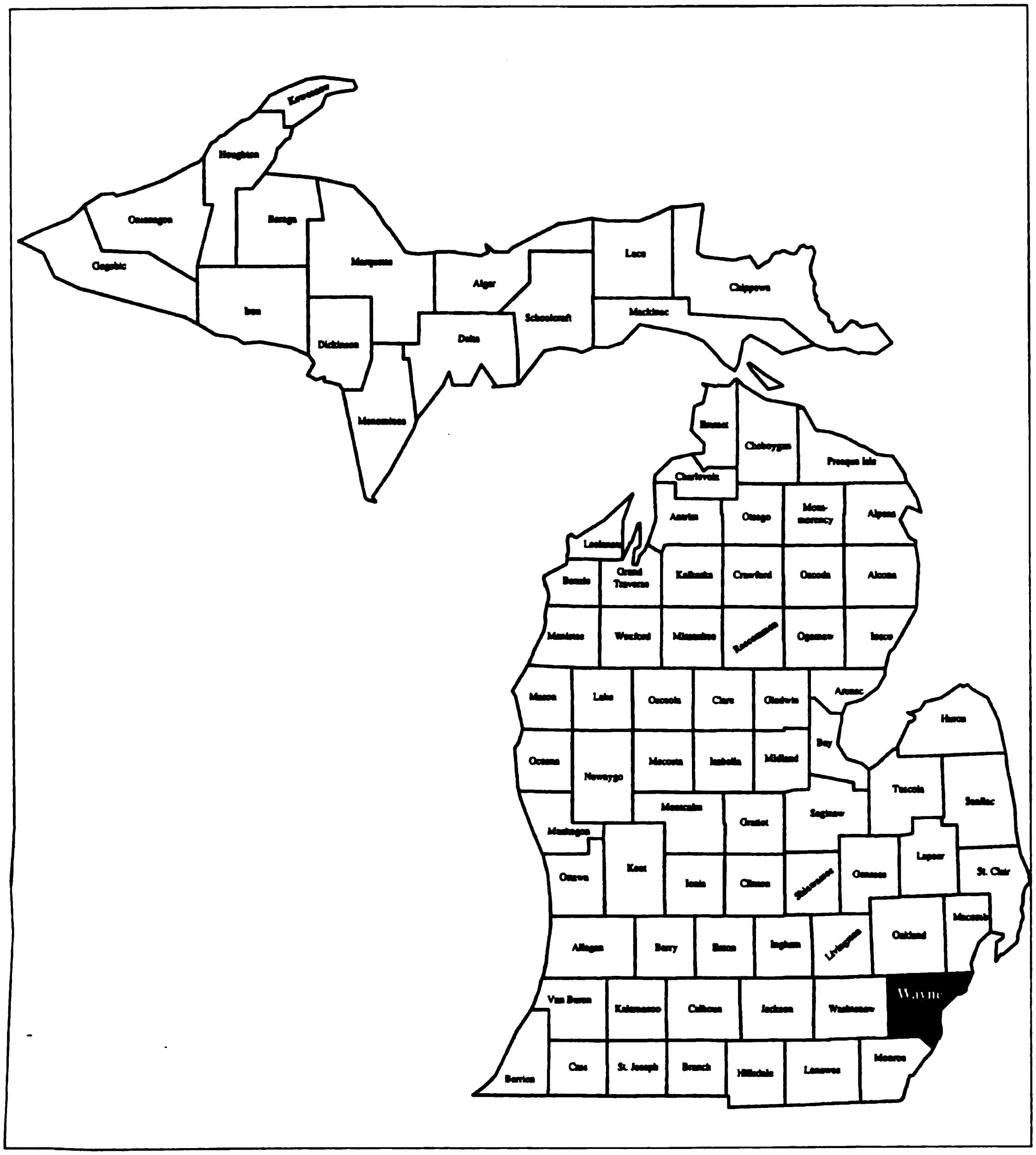
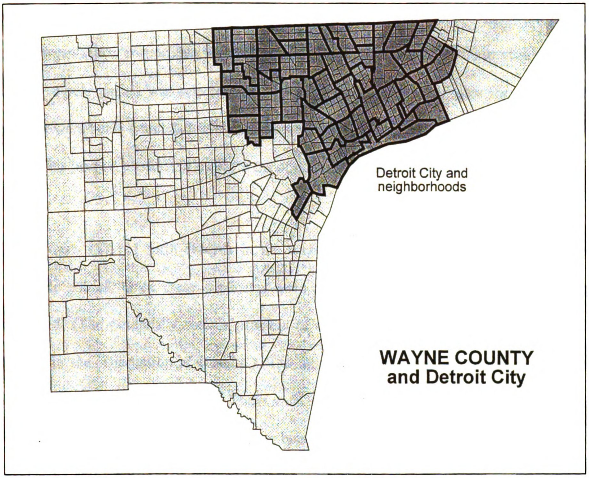


Figure 4.2
Map showing the 321 census tracts (fine lines) and 47 neighborhoods (bold lines) of Detroit within Wayne County (See Appendix B for names of neighborhoods)



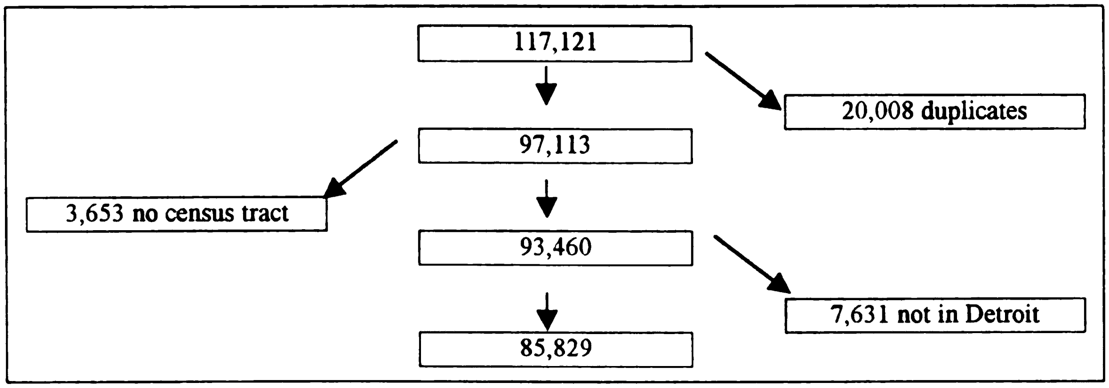
These sub-communities facilitate assessment of needs and planning of services by the USC, the Detroit City Planning Commission, and other community organizations. There are two additional Cities within the administrative boundaries of the City of Detroit, namely Highland Park and Hamtramck. However, they are politically self-governing and, consequently, were excluded from the study.

GEOCODED BIRTH CERTIFICATES

The Birth Certificates of all live births in Wayne County, between 1984 and 1988, were obtained from the Michigan Department of Community Health (MDCH), which is the state organization responsible for the collection and maintenance of these vital records. This five-year period was selected for analysis because birth certificates for the City of Detroit were being geocoded to census tract of maternal residence (manually!) during this time. This made it possible to evaluate the population-based demand for NICU care.

There were 117,121 birth records in the original file, of which 20,008 (17.1%) were duplicate entries. Once these duplicates were removed, a total of 97,113 birth records remained. (The potentially serious problem of duplicate vital records will be addressed further in the 'Discussion of Results'). The mother's census tract of residence was not present on 3,653 (3.8%) records. These were assumed to be outside of Detroit because only City of Detroit birth certificates were being geocoded. Therefore, these were deleted leaving 93,460 records. The mother's census tract of residence was then used to identify 85,829 (91.8%) infants born to mothers residing within the City of Detroit. (Figure 4.3). The 7,631 (8.2%) birth certificates with census tracts outside the City of Detroit were assumed to be truly outside Detroit although they may have been individuals who were incorrectly geocoded.

FIGURE 4.3
Origin of the final birth certificate file.



GEOCODED LINKED BIRTH-DEATH CERTIFICATES

An electronic file containing the death certificates of infants born to mothers residing within Wayne County between 1980 and 1988 linked to the corresponding death certificates (from the same 9 year period) was obtained from the Michigan Department of Community Health, which is responsible for collection and maintenance of these vital records. Among infants born to mothers residing in Wayne County between 1984 and 1988, 2,710 deaths occurred. A total of 176 (6.5%) records were geocoded to census tracts outside the limits of the City of Detroit (these geocoded records may have been from the City of Detroit but incorrectly coded as a result of data entry errors). Therefore, these records were eliminated from the database. In addition, 700 (25.8%) records were eliminated because the census tract of maternal residence was not identified. These were assumed to be in Wayne County and not in the City of Detroit because only records of infants born within the City of Detroit were being geocoded. These were removed leaving a total of 1,834 death certificates and corresponding death certificates of infants born between 1984 and 1988 to mothers residing within the City of Detroit and dying before their first birthday between 1984 and 1989.

MICHIGAN INPATIENT DATABASE RECORDS

The records of all infants born to mothers residing within the Detroit metropolitan area 5-digit postal codes between 1984 and 1988 were obtained from the Michigan Inpatient Database (MIDB). This data set is maintained by the Michigan Health Data Corporation (MHDC) for the Michigan Hospital Association (MHA) at the time of this study. These records contain outcome data for each infant: length of stay, diagnostic codes, and procedural codes (Appendix C). Using the software Statistical Package for the Social Sciences 8.0 (SPSS), an attempt was made to link MIDB records to the combined (linked) birth and death certificate records.[82] All data sets were anonymous and had no common unique identifier. Therefore, a linking procedure was used that included 10 fields common to each file. Unfortunately, even these 10 fields were not sufficient to unambiguously identify each individual. Therefore, outcome data from the MIDB were not utilized. This made it necessary to impute NICU admission status and length of stay using a rational procedure devised by the author (described below).

LINKING BIRTH AND LINKED BIRTH-DEATH CERTIFICATE FILES

The Birth certificate and linked Birth-Death certificate files were linked using variables common to both. These variables included date of birth, birth residence Census Tract

(CT), Minor Civil Division (MCD) of birth occurrence, gender at birth, race at birth, plurality, and birthweight in grams. Initially, there were 85,829 records in this linked birth and death certificate file. There were 559 infant records in this linked file with a birthweight less than 500 grams. These were deleted from the file because infants with these values would not typically survive and would not be offered neonatal intensive care. This left 85,270 birth records linked to 1,275 corresponding death records. In order to assure valid comparisons to national data, national mortality and low-birthweight rates were calculated using births of 500 grams and greater. This linked data file contains 118 variables (see appendix D).

CENSUS DATA

Data from the 1990 National Census was obtained from the Census Bureau. A number of Census Tract-specific demographic, economic and environmental variables were either extracted or computed from the Census data. In addition, one demographic and one economic variable were obtained from the birth certificates. The neighborhoods were grouped in quartiles for each census tract variable for bivariate analysis.

The demographic variables included:

- Percent black population (calculated)
- Percent of population 15 years of age or younger (calculated)
- Percent of population 65 years of age or greater (calculated)
- Median maternal age in years (obtained from birth certificates)

The economic variables included:

- Percent of homes with at least one car (calculated)
- Median household income in 1990 $US (extracted)
- Percent of households above 150% of the federal poverty level (calculated)
- Percent of adult population without a high school education (calculated)
- Percent of homes with female head of household (calculated)
- Median years of maternal education (obtained from birth certificates)

The environmental variables included:

- Percent vacant housing (calculated)
- Percent renter occupied housing (calculated)
- Median property value in 1990 $US (extracted)
- Percent crowding (calculated)
- Percent housing constructed before 1940 (calculated)

The neighborhood demographic, economic, and environmental characteristics of the birth residence of each infant were linked to each infant record.

ESTIMATING DEMAND AND COST

Four variables necessary to impute NICU demand and cost had to be estimated because these data could not be linked from the MIDB: NICU admission (yes, no), length of hospital stay (days), demand per day (NICU beds occupied), incremental cost of hospital stay ($US, 1988). The demand could then be calculated by multiplying the number of admissions by the birthweight-specific length of stay and the cost could be determined by multiplying the number of admissions by the birthweight-specific cost. The incremental cost could then be calculated by subtracting the "usual" cost from the "actual" cost.

NICU ADMISSION

Any infant born at or before completing 34 weeks of gestation was classified as a "high probability" NICU admission (HPA). Likewise, any infant weighing less than or equal to 2000 grams was also placed in the HPA category. These criteria parallel two of the clinical criteria used to assign infants to NICU care in the only prior population-based study of NICU demand in the United States.[5] A study of 13,881 consecutive births in Boston revealed that 4.3% of normal birthweight infants ($\geq$ 2500 grams) required admission to a NICU.[60] The total number of normal birthweight infants, infants weighing more than 2,000 grams, and infants more than 34 weeks gestation in each neighborhood in the City of Detroit neighborhood was calculated. This number was then multiplied by a factor of 0.043 to obtain the estimated number of infants who were assigned to NICU admission status as low-probability admissions (LPA). For example, there were 79,529 infants weighing more than 2,000 grams and more than 34 weeks gestation. Therefore, there were 3,420 (79,529 x 0.043) LPA infants assigned to NICU admission status in Detroit.

LENGTH OF STAY

The length of NICU stay for all HPA infants was assigned according to birthweight (Table 4.1).[62] For example, the average length of stay for the City of Detroit was 24.93 days. All LPA infants assigned to NICU admission status were given a length of stay of 7.6 days based on the length of stay of normal birthweight infants admitted to a NICU in the metropolitan area of Boston.[60]

TABLE 4.1
Average hospital stay and cost according to birthweight category (Schwartz 1989)

Birthweight category (grams)	**Average length of stay** (days)	**Average cost of stay** (1988, $US)
500 - 749	33.4	22,782
750 - 999	53.0	33,206
1000 - 1249	47.7	24,803
1250 - 1499	35.9	17,459
1500 - 1999	20.5	9,157
2000 - 2499	7.5	2,821
≥ 2500	3.5	718

NEIGHBORHOOD NICU DEMAND PER DAY

The NICU bed demand generated by HPA infants in each neighborhood was estimated by determining the average length of stay for all infants assigned to NICU status within each neighborhood and multiplying this by the number of NICU admissions in each neighborhood. This total was then divided by 1,825 (or 365 days x 5 years) to estimate the average number of beds needed each day by each neighborhood for HPA infants. The NICU bed demand per 1,000 live births was determined by dividing this figure by the number of births in the neighborhood and multiplying by 1,000 (Table 4.2).

TABLE 4.2
Calculation of NICU bed demand (per day and per 1,000 live births for infants weighing ≤ 2,000 grams or ≤ 34 weeks) – high probability admissions (HPA)

	HPA ALOS	HPA NICU Admits	Total live births	HPA NICU beds/day	HPA NICU beds per 1000 live births
Estimation procedure	**a**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	24.93	5,741	85,270	78.42	4.60

A similar process was used to calculate the demand generated by LPA infants, but the LPA average length of stay of 7.6 days was applied to these infants. The total demand for LPA and HPA admission was then derived by adding HPA and LPA demand (Table 4.3).

TABLE 4.3
Calculation of NICU bed demand (per day and per 1,000 live births for infants weighing > 2,000 grams or > 34 weeks) - low probability admissions (LPA) and total (LPA + HPA)

	LPA ALOS	LPA NICU Admits	Total live births	LPA NICU beds/day	LPA (Total) NICU beds per 1000 live births
Estimation procedure	**a**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	7.6	3,420	85,270	14.24	0.84 (5.44)

COST AND INCREMENTAL COST PER NEIGHBORHOOD PER BIRTH

The cost of stay for all HPA babies was assigned based on birthweight (Table 4.1).[62] The average cost of stay for each NICU admission stratified by birthweight within each neighborhood was multiplied by the number of NICU admissions to determine the total cost for the five years of the study. The yearly cost for NICU admissions was determined by dividing this number by five. The incremental cost for low-birthweight NICU care for each birth in each neighborhood was computed by dividing the total cost for each neig

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neighborhood by the number of births in each neighborhood and subtracting the average cost of caring for normal birthweight infants (Table 4.4).

TABLE 4.4
Calculation of the incremental cost (per year and per birth for infants weighing ≤ 2,000 grams or ≤ 34 weeks) – high probability admissions (HPA)

	HPA ACOS* ($)	HPA NICU admits	Total live births	HPA Incremental Cost/year (million $)	HPA Incremental Cost per birth ($)
Estimation procedure	**a**	**b**	**c**	**$(a*b-718*b)/5/10^3$**	**(a*b-718*b)/c**
Example (City of Detroit)	12,930	5,741	85,270	14.02	822

The incremental cost of caring for LPA NICU admissions was estimated by assigning the average cost of caring for similar infants in Boston ($11,504, for 1989-90) and subtracting the average cost of caring for healthy normal-birthweight infants.[60] The total incremental cost per birth was calculated by adding the HPA and LPA costs (Table 4.5).

TABLE 4.5
Calculation of the incremental cost (per year and per birth for infants weighing > 2,000 grams or > 34 weeks) – low probability admissions (LPA) and total

	LPA ACOS* ($)	LPA NICU admits	Total live births	LPA Incremental Cost/year (million $)	LPA (Total) Incremental Cost per birth ($)
Estimation procedure	**a**	**b**	**c**	**$(a*b-718*b)/5/10^3$**	**(a*b-718*b)/c**
Example (City of Detroit)	11,504	3,420	85,270	7.38	433 (1,255)

STATISTICAL MODELS

NICU DEMAND AND COST

A linear regression model was chosen to analyze the relationship between birthweight and NICU demand, and to model the relationship between birthweight and incremental NICU cost. The VLBWR was chosen as the initial variable to assess in each model because VLBW infants have the longest hospital stays and are less likely to be misclassified as a result of genetic determinants of birthweight. The contribution of other continuous variables was explored. The model was compared to the actual NICU demand in Detroit and was tested using data from the three population-based studies of NICU bed demand.

THE EFFECT OF NICU SIZE AND DAY-TO-DAY VARIATION IN DEMAND FOR NICU CARE

A mathematical model was also developed to evaluate the effect of day-to-day variation in NICU bed demand and the effect of inter-facility cooperation. This model incorporated the output of the linear regression model of NICU bed demand in a *poisson* distribution model. A *poisson* model was chosen because demand for hospital beds for non-elective cases has been demonstrated to have this distribution.[83],[70] Therefore, the day-to-day variation in demand for NICU beds would be expected to follow a *poisson* distribution. This distribution is as follows:

Where:

p = Proportion of days n beds are adequate
n = number of beds available
b = mean number of beds occupied (demand)
e = 2.7182
i = an integer from 0 to n

$$p(n,b) = \sum_{i=0}^{n} e^{b}\, b^{i}/i!$$

In this model, 110 beds within Detroit were distributed to one NICU of 110 beds, two NICUs of 55 beds each, five NICUs of 20 beds each, and ten NICUs of 11 beds each. The proportion of days 110 beds would be adequate to meet the demand in Detroit was then calculated using the above formula.

THE EFFECT OF VARYING TOLERANCE FOR "NO BED AVAILABLE" DAYS

The relationship between different levels of tolerance for "no bed available" days and the number of beds required to meet the demand for NICU beds will be demonstrated. This will be done by demonstrating the number of NICU beds needed to meet the demand 100%, 96%, 86 %, and 74% of the days respectively. For this model, it is assumed that there is an average daily demand for 93 NICU beds and that the NICU beds are equally divided among four hospitals. It will also be assumed that the total demand is equally divided among the four hospitals.

"WHAT IF" SCENARIOS

The effect of four possible scenarios on mean NICU bed occupancy and incremental NICU cost was explored: The effect of limiting resuscitation to infants weighing, respectively, $\geq$ 600 grams, $\geq$ 700 grams, and $\geq$ 750 grams, and the effect of increasing all birthweights by 100 grams. The effect of limiting resuscitation of very small infants was modeled by removing infants of the selected weight groups from the database, calculating the very low-birthweight rate, and estimating the mean occupancy and demand with the linear regression model. The effect of increasing the weight of all infants 100 grams was modeled by adding 100 grams to each infant's birthweight, repeating the length of stay and cost estimate for each infant, and recalculating the mean bed occupancy and cost for infants with high probability of NICU admission.

STATISTICAL ANALYSIS

Statistical analyses were performed using the software Statistical Package for the Social Sciences 8.0 (SPSS).[82] For 27 infants with unknown birthweight the median birthweight for the estimated gestational age of the infant was assigned to these records. The frequency of individual variables was determined and Mantel-Haenszel chi-square analysis was used to establish odds ratios (ORs) and 95% confidence intervals (CI) for bivariate associations. Bivariate analysis of associations included analysis of infant mortality rates but focused on neonatal mortality because neonatal mortality is more closely related to NICU care than is infant mortality. Likewise, bivariate analysis of associations included low-birthweight rates but focused on very low-birthweight rates because these rates are less affected by genetic determinants of birthweight than are low-birthweight rates (This is especially true as the birthweight approaches 2500 grams).

STATISTICAL SIGNIFICANCE

Some of the associations identified in this study are likely to be due to chance associations because of the large number of variables analyzed. A confidence level of 95% was chosen to identify statistically significant associations and each association was assessed for plausibility, consistency with existing literature, and consistency with different exposure levels of the variable. All odds ratios were rounded to a single decimal place and significance was determined after rounding.

AVOIDING ECOLOGICAL FALLACY

Associations among variables identified in this study, and all population-based studies are susceptible to the ecological fallacy (falsely assuming that an association noted between a population characteristic and an outcome also holds true between that characteristic and the outcome at the individual level). Therefore, the author has not assumed that any ecological association is true at the level of the individual.

VALIDATION OF DATABASE AND MODELS

The data set was analyzed for mean birthweight, racial distribution, VLBWR, LBWR, IMR, and NMR both before and after records were excluded to create the final data set. The differences that occurred as a result of excluding records (as noted above) were noted.

The model demonstrating the relationship between VLBW and demand was tested using the "known" demand in Detroit and four other populations.

SUMMARY

The methods used in this study have been presented in this chapter. An overview of the study, the geographic area of interest, the procedure used to link the databases, the methods used to estimate NICU demand and cost, and the methodological approach to modeling and analysis have been presented. In the next chapter, the results will be presented including descriptive statistics, bivariate analysis, estimation results, modeling results, and validation of the database and models.

Chapter 5

RESULTS

The descriptive and analytic statistics, estimates of demand and cost, statistical models, and validation of the database and models are presented in this chapter. These will be presented in the following order: descriptive statistics, bivariate analysis, results of estimation procedures, modeling results, and steps taken to assess the limitations of the study.

DESCRIPTIVE STATISTICS

This section presents a description of neighborhood characteristics and birthweight-specific infant and neonatal mortality. The neighborhood characteristics include median birthweight, median gestational age, demographic variables, economic variables, and environmental variables. The relationship between birthweight and mortality is also described. Descriptive statistics are divided into the following categories:

- Neighborhood-specific birthweight and gestational-age distributions
- Neighborhood-specific low-birthweight and very low-birthweight rates
- Neighborhood-specific infant and neonatal mortality rates

- Birthweight and gestational-age-specific infant and neonatal mortality
- Interaction between birthweight, gestational-age and infant and neonatal mortality
- Neighborhood demographic, economic, and environmental characteristics

NEIGHBORHOOD BIRTHWEIGHT AND GESTATIONAL-AGE DISTRIBUTION

There were 85,270 infants born to mothers residing in the City of Detroit between 1984 and 1988. The weight at birth of these infants ranged from 500 gram to 7,165 grams. The distribution was normal with a mean of 3,142 grams and a median of 3,203 grams. The median neighborhood-specific birthweight ranged from a minimum of 3,062 grams and a maximum of 3,400 grams (Table 5.1). The mean (39 weeks) and median (40 weeks) gestational age for every neighborhood was the same.

NEIGHBORHOOD-SPECIFIC LOW-BIRTHWEIGHT AND VERY LOW-BIRTHWEIGHT RATES

The overall LBW rate was 13% and it ranged from 8% to 19% among the neighborhoods. Furthermore, the LBW rate was higher than the national LBW rate in every neighborhood in the City of Detroit. The overall VLBW rate was 2% and it varied from 1% to 4%. The VLBW rate of eleven neighborhoods was comparable to the national VLBW rate (Table 5.2).

NEIGHBORHOOD-SPECIFIC INFANT AND NEONATAL MORTALITY RATES

The overall IMR was 15/1,000 live births and the IMR ranged from a low of seven to a high of 24/1,000 live births (Table 5.2). The overall IMR was above the national average, but 23 neighborhoods had an IMR comparable to the national IMR. The overall NMR was 9/1,000 live births for all neighborhoods and ranged from 3 to 14/1,000 live births. The NMR was below the national rate in one neighborhood and comparable to the national NMR in 35 neighborhoods (Table 5.2).

Table 5.1
Birthweight distribution for selected neighborhoods in order of increasing mean birthweight - Detroit, Michigan (1984 -1988) (See Appendix E for listing of all neighborhoods)

Five neighborhoods with the lowest mean birthweight		**Distribution**			
Code	**Geographic Unit**	**Low**	**High**	**Mean***	**Median**
34	Central	520	4990	2986	3062
33	Rosa Parks	510	5160	3038	3090
39	Chene	520	4961	3047	3090
42	Mack	500	5443	3049	3110
41	St. Jean	510	5160	3050	3116
Five neighborhoods with the highest mean birthweight		**Distribution**			
Code	**Geographic Unit**	**Low**	**High**	**Mean**	**Median**
14	Finney	510	5120	3275	3317
35	Chadsey	540	5528	3271	3317
13	Denby	500	5103	3301	3345
27	Rouge	595	5160	3303	3345
1	Redford	520	5330	3336	3400
0	City of Detroit	500	7165	3142	3203

*The national mean was 3420 between 1986 and 1987

BIRTHWEIGHT AND GESTATIONAL-AGE-SPECIFIC INFANT AND NEONATAL MORTALITY

Infant and neonatal mortality increased as birthweight decreased (Table 5.3). Likewise, infants with gestational ages greater than 43 weeks had greater infant and neonatal mortality rates than infants with gestational ages of 36 to 42 weeks. Otherwise, both infant and neonatal mortality increased as gestational-age decreased. This effect was greater for neonatal mortality than for infant mortality (Table 5.4).

Table 5.2

Low-birthweight rate, very low birthweight, neonatal mortality rate, and infant mortality rate by Neighborhood in the City of Detroit (1984 – 1988) ranked by the very low birthweight rate and Mantel-Haenszel odds ratio with 95% confidence interval (C.I.)

Code	Geographic Unit	% LBW	Odds Ratio (C.I.)	% VLBW	Odds Ratio (C.I.)	NMR	Odds Ratio (C.I.)	IMR	Odds Ratio (C.I.)
-	United States	6.82	Reference	1.20	Reference	6.70	Reference	10.37	Reference
44	Delray-Springwells	9.51	1.44 (1.25, 1.64)	1.22	1.02 (0.71, 1.46)	8.16	1.22 (0.79, 1.90)	13.06	1.26 (0.89, 1.79)
45	Clark Park	9.62	1.45 (1.24, 1.70)	1.31	1.09 (0.72, 1.65)	5.13	0.76 (0.40, 1.47)	9.11	0.88 (0.54, 1.44)
10	Grant	10.10	1.53 (1.20, 1.96)	1.42	1.19 (0.64, 2.22)	4.27	0.64 (0.20, 1.98)	9.96	0.96 (0.46, 2.02)
13	Denby	9.32	1.40 (1.19, 1.66)	1.45	1.21 (0.81, 1.82)	8.47	1.27 (0.75, 2.14)	10.89	1.05 (0.66, 1.67)
27	Rouge	8.11	1.20 (1.01, 1.44)	1.45	1.21 (0.81, 1.82)	4.23	0.63 (0.30, 1.33)	8.47	0.81 (0.48, 1.38)
14	Finney	8.68	1.30 (1.14, 1.48)	1.54	1.29 (0.95, 1.74)	3.23	0.48 (0.25, 0.92)	7.18	0.69 (0.44, 1.07)
1	Redford	8.20	1.22 (1.01, 1.47)	1.65	1.38 (0.93, 2.05)	5.95	0.89 (0.46, 1.71)	10.58	1.02 (0.62, 1.67)
6	Palmer Park	9.39	1.41 (1.08, 1.85)	1.78	1.49 (0.82, 2.71)	11.33	1.70 (0.81, 3.58)	16.18	1.57 (0.84, 2.93)
47	Central Business District	12.35	1.92 (1.20, 3.07)	1.85	1.55 (0.50, 4.87)	12.35	1.85 (0.46, 7.48)	18.52	1.80 (0.57, 5.64)
46	Lafayette	13.92	2.21 (1.68, 2.91)	1.89	1.58 (0.79, 3.19)	4.72	0.70 (0.18, 2.82)	14.15	1.37 (0.61, 3.07)
48	Indian Village	14.06	2.24 (1.57, 3.18)	2.34	1.98 (0.88, 4.44)	3.91	0.58 (0.08, 4.15)	19.53	1.90 (0.78, 4.61)
17	Davison	12.17	1.89 (1.65, 2.17)	1.74	1.46 (1.03, 2.06)	6.32	0.94 (0.54, 1.67)	11.59	1.12 (0.73, 1.70)
24	Brightmoor	11.83	1.83 (1.61, 2.08)	1.75	1.46 (1.07, 2.00)	7.86	1.17 (0.74, 1.87)	16.59	1.61 (1.17, 2.22)
35	Chadsey	9.95	1.51 (1.30, 1.75)	1.96	1.65 (1.20, 2.26)	9.55	1.43 (0.91, 2.25)	15.59	1.51 (1.06, 2.15)
7	State Fair	10.83	1.66 (1.42, 1.94)	2.07	1.74 (1.23, 2.45)	10.64	1.60 (0.99, 2.57)	18.77	1.83 (1.27, 2.62)
11	Mt. Olivet	10.06	1.53 (1.34, 1.74)	2.10	1.77 (1.34, 2.32)	11.49	1.72 (1.20, 2.49)	13.86	1.34 (0.96, 1.87)
2	Evergreen	11.24	1.73 (1.54, 1.94)	2.29	1.93 (1.51, 2.47)	8.11	1.21 (0.80, 1.83)	13.04	1.26 (0.91, 1.74)
23	Rosedale Park	9.97	1.51 (1.26, 1.81)	2.32	1.95 (1.36, 2.81)	6.18	0.92 (0.46, 1.85)	9.27	0.89 (0.51, 1.58)
49	East-Riverside	14.44	2.31 (1.92, 2.78)	2.33	1.97 (1.28, 3.03)	11.11	1.67 (0.89, 3.11)	18.89	1.84 (1.14, 2.97)
22	Cerveny	13.47	2.13 (1.85, 2.45)	2.37	2.00 (1.46, 2.74)	7.72	1.15 (0.67, 1.99)	13.65	1.32 (0.87, 1.99)
38	University	13.08	2.06 (1.71, 2.48)	2.37	2.00 (1.32, 3.02)	14.42	2.17 (1.28, 3.68)	17.51	1.70 (1.05, 2.75)
28	Brooks	12.25	1.91 (1.72, 2.12)	2.44	2.06 (1.66, 2.57)	9.54	1.43 (1.01, 2.02)	14.31	1.39 (1.04, 1.84)
25	Grandmont	11.37	1.75 (1.48, 2.07)	2.45	2.07 (1.46, 2.92)	6.69	1.00 (0.52, 1.92)	13.37	1.29 (0.81, 2.06)
12	Burbank	10.80	1.65 (1.46, 1.87)	2.48	2.10 (1.64, 2.68)	10.54	1.58 (1.09, 2.29)	13.93	1.35 (0.97, 1.86)
0	City of Detroit	12.70	2.00 (1.96, 2.04)	2.51	2.13 (2.04, 2.23)	8.90	1.33 (1.24, 1.43)	14.95	1.45 (1.37, 1.53)

[shaded box] = Significantly different from national rate

(Continued)

Table 5.2 (continued)
Low-birthweight rate, very low birthweight, neonatal mortality rate, and infant mortality rate by Neighborhood in the City of Detroit (1984 – 1988) ranked by the very low birthweight rate and Mantel-Haenszel odds ratio with 95% confidence interval (C.I.)

Code	Geographic Unit	% LBW	Odds Ratio (C.I.)	% VLBW	Odds Ratio (C.I.)	NMR	Odds Ratio (C.I.)	IMR	Odds Ratio (C.I.)
4	Pembroke	11.96	1.86 (1.57, 2.19)	2.50	2.11 (1.49, 2.98)	10.60	1.59 (0.94, 2.69)	15.90	1.54 (1.00, 2.37)
5	Bagley	11.09	1.70 (1.43, 2.02)	2.51	2.12 (1.50, 2.99)	4.56	0.68 (0.30, 1.51)	9.87	0.95 (0.55, 1.64)
29	Mackenzie	13.24	2.08 (1.89, 2.31)	2.54	2.15 (1.73, 2.66)	8.77	1.31 (0.91, 1.89)	14.21	1.37 (1.03, 1.83)
15	Connor	13.04	2.05 (1.86, 2.25)	2.56	2.17 (1.77, 2.66)	8.18	1.22 (0.85, 1.75)	13.36	1.29 (0.97, 1.71)
26	Cody	11.78	1.82 (1.59, 2.09)	2.59	2.19 (1.67, 2.88)	8.80	1.32 (0.83, 2.09)	17.11	1.66 (1.19, 2.32)
9	Pershing	12.18	1.89 (1.63, 2.20)	2.67	2.26 (1.67, 3.06)	7.46	1.11 (0.63, 1.97)	10.57	1.02 (0.63, 1.64)
21	Harmony Village	14.24	2.27 (2.06, 2.50)	2.70	2.28 (1.85, 2.83)	7.76	1.16 (0.78, 1.72)	12.72	1.23 (0.90, 1.67)
43	Boynton	13.70	2.17 (1.74, 2.71)	2.74	2.32 (1.45, 3.71)	12.18	1.83 (0.91, 3.67)	15.22	1.47 (0.79, 2.75)
41	St. Jean	16.27	2.65 (2.36, 2.98)	2.85	2.41 (1.87, 3.12)	13.76	2.07 (1.43, 2.99)	19.92	1.94 (1.43, 2.63)
39	Chene	16.11	2.62 (2.30, 2.99)	2.94	2.49 (1.87, 3.32)	9.80	1.47 (0.90, 2.40)	20.82	1.76 (1.32, 2.35)
3	Greenfield	12.48	1.95 (1.72, 2.21)	2.96	2.52 (1.97, 3.21)	13.72	2.06 (1.45, 2.94)	16.81	1.63 (1.18, 2.25)
32	Tireman	15.23	2.45 (2.19, 2.75)	2.98	2.53 (1.98, 3.22)	8.88	1.33 (0.86, 2.06)	15.54	1.51 (1.08, 2.10)
8	Nolan	14.00	2.22 (1.98, 2.50)	3.02	2.56 (2.02, 3.26)	8.31	1.24 (0.79, 1.95)	17.50	1.70 (1.24, 2.32)
37	Jeffries	15.70	2.54 (2.04, 3.18)	3.07	2.61 (1.63, 4.17)	11.95	1.79 (0.85, 3.78)	17.06	1.67 (0.89, 3.09)
40	Kettering-Butzel	15.53	2.51 (2.26, 2.79)	3.13	2.66 (2.13, 3.32)	10.43	1.56 (1.07, 2.29)	18.16	1.94 (1.43, 2.63)
42	Mack	16.43	2.69 (2.41, 2.99)	3.22	2.74 (2.18, 3.44)	8.04	1.20 (0.77, 1.89)	16.09	1.56 (1.13, 2.15)
30	Winterhalter	14.63	2.34 (2.04, 2.68)	3.24	2.76 (2.10, 3.63)	12.85	1.93 (1.26, 2.97)	15.91	1.54 (1.05, 2.27)
16	Airport	14.59	2.33 (2.07, 2.63)	3.28	2.80 (2.21, 3.54)	10.94	1.64 (1.10, 2.45)	19.61	1.91 (1.41, 2.58)
31	Durfee	14.36	2.29 (2.04, 2.56)	3.29	2.80 (2.24, 3.50)	7.82	1.17 (0.74,1.84)	16.87	1.64 (1.20, 2.23)
33	Rosa Parks	16.02	2.61 (2.33, 2.91)	3.40	2.90 (2.32, 3.62)	9.35	1.40 (0.92, 2.13)	16.99	1.65 (1.21, 2.25)
36	Condon	15.27	2.46 (2.11, 2.87)	3.60	3.07 (2.28, 4.14)	12.79	1.92 (1.17, 3.15)	23.18	2.26 (1.57, 3.27)
34	Central	19.37	3.28 (2.91, 3.70)	3.97	3.40 (2.67, 4.33)	10.34	1.55 (0.97, 2.47)	23.56	2.30 (1.69, 3.14)
20	McNichols	14.77	2.37 (2.01, 2.79)	4.18	3.59 (2.68, 4.81)	12.46	1.87 (1.10, 3.17)	23.13	2.26 (1.53, 3.33)
0	City of Detroit	12.70	2.00 (1.96, 2.04)	2.51	2.13 (2.04, 2.23)	8.90	1.33 (1.24, 1.43)	14.95	1.45 (1.37, 1.53)

[shaded box] = Significantly different from national rate

Table 5.3
Birthweight-specific infant and neonatal mortality rates (per 1000 live births)
Detroit, Michigan (1984-1988)

Birthweight (grams)	Infant Deaths/Births	IMR	Neonatal Deaths/Births	NMR
500 – 749	347/498	696.8	321/498	644.6
750 – 999	137/479	286.0	106/479	221.3
1000 – 1249	51/515	99.0	34/515	66.0
1250 – 1499	55/650	84.6	33/650	50.8
1500 – 1749	43/ 841	51.1	28/841	33.3
1750 – 1999	54/1,323	40.8	27/1,323	20.4
2000 – 2249	54/2,229	24.2	25/2,229	11.2
2250 – 2499	80/4,293	18.6	33/4,293	7.7
≥ 2500	454/74,442	6.1	152/74,442	2.0

Table 5.4
Gestational age-specific infant and neonatal mortality rates – Detroit, Michigan (1984-1988)

Gestational Age (weeks)	Infant Deaths/Births		IMR	Neonatal Deaths/Births		NMR
< 28	452	927	487.6	398	927	429.3
28 - 31	144	1,329	108.4	108	1,329	81.3
32 - 35	128	3,917	32.7	61	3,917	15.6
36 – 37	97	6,885	14.1	34	6,885	4.9
38 – 42	445	71,376	6.2	150	71,376	2.1
> 43	9	836	10.8	8	836	9.6

INTERACTION BETWEEN GESTATIONAL AGE, BIRTHWEIGHT, AND MORTALITY

PTB was associated with a high IMR for infants who were either LBW or NBW but the effect was greater for LBW preterm (IMR of 114/1,000 live births) than for NBW (IMR of 18/1,000 live births) infants. The IMR was also greater in term, LBW (IMR of 22/1,000 live births) than term, NBW (IMR of 6/1,000 live births) infants (Table 5.5).

TABLE 5.5
Infant Mortality by gestational age category and birthweight category – Detroit, Michigan (1984-1988)

	Birthweight < 2500 (LBW)	Birthweight ≥ 2500 (NBW)
Estimated gestational age	IMR/1,000 live births	IMR/1,000 live births
< 37 weeks (Preterm)	114.0	18.3
≥ 37 weeks (Term)	22.2	5.6

PTB was also associated with high infant mortality in infants who had intrauterine growth retardation (IUGR or below the 10th percentile for gestational age) and infants who did not have IUGR, but the effect was greater in IUGR (IMR = 145/1,000 live births) than in non-IUGR (8/1,000 live births) infants. However, the IMR was also greater in term, IUGR (IMR of 22/1,000 live births) than term, non-IUGR (IMR of 6/1,000 live births) infants (Tables 5.6).

Table 5.6
Infant mortality by gestational age category and IUGR* status – Detroit, Michigan (1984-1988)

	Birthweight for gestational age	
Estimated gestational age	IUGR – IMR/1,000 live births	Normal - IMR/1,000 live births
< 37 weeks (Preterm)	145.0	7.8
≥ 37 weeks (Normal)	17.1	5.5

*IUGR intrauterine growth retardation = birthweight < 10th percentile for the gestational age

Most infant mortality was neonatal when PTB was present. In fact, the only exception was among preterm NBW infants in whom neonatal mortality accounted for 45% of infant mortality. The effect of PTB on the NMR is seen in tables 5.10 through 5.14. The percent infant mortality associated with LBW was neonatal (78% or 88.4/114) in preterm infants and post-neonatal (52% or 100 - 10.7/22.2) in term infants (Table 5.7).

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Table 5.7
Infant and neonatal mortality rates by gestational age category for **low-birthweight** infants
Detroit, Michigan (1984-1988)

Gestational Age (weeks)	LBW Infant Deaths/Births		IMR/1,000 Live births	LBW Neonatal Deaths/Births		NMR/1,000 Live births
< 37 weeks (Preterm)	721	6,327	114.0	559	6,327	88.4
≥ 37 weeks (Term)	100	4,501	22.2	48	4,501	10.7

Infant mortality in NBW infants occurred in the post-neonatal time period regardless of whether the infant was term or preterm, but neonatal death was more frequent among preterm (45% **or** 8.3/18.3) than among term (32% **or** 1.8/5.6) births (Table 5.8).

Table 5.8
Infant and neonatal mortality rates by gestational age category for **normal birthweight** infants
Detroit, Michigan (1984-1988)

Gestational Age (weeks)	NBW Infant Deaths/Births		IMR/1,000 Live births	NBW Neonatal Deaths/Births		NMR/1,000 Live births
< 37 weeks (Preterm)	51	2,781	18.3	23	2,781	8.3
≥ 37 weeks (Term)	403	71,661	5.6	129	71,661	1.8

Infant mortality associated with IUGR was neonatal (81% **or** 117.6/145) in preterm infants and post-neonatal (56% **or** 1 – 7.6/17.1) in term infants (Table 5.9).

Table 5.9
Infant and neonatal mortality rates by gestational age category for infants with IUGR
Detroit, Michigan (1984-1988)

Gestational Age (weeks)	IUGR Infant Deaths/Births		IMR/1,000 Live births	IUGR Neonatal Deaths/Births		NMR/1,000 Live births
< 37 weeks (Preterm)	127	876	145.0	103	876	117.6
≥ 37 weeks (Term)	122	7,118	17.1	54	7,118	7.6

Infant mortality associated with non-IUGR births was neonatal (74% **or** 58.2/78.4) in preterm infants and post-neonatal (67% **or** 1 – 1.8/5.5) in term infants (Table 5.10).

Table 5.10
Infant and neonatal mortality rates by gestational age category for infants who **don't have IUGR**
Detroit (1984 to 1988)

Gestational Age (weeks)	Non-IUGR Infant Deaths/Births		IMR/1,000 Live births	Non-IUGR Neonatal Deaths/Births		NMR/1,000 Live births
< 37 weeks (Preterm)	645	8,232	78.4	479	8,232	58.2
≥ 37 weeks (Term)	381	69044	5.5	123	69,044	1.8

"All risks" infants (PTB, LBW, and IUGR combined) and "no risk" infants (NBW, term, and non-IUGR) respectively had the Highest and Lowest IMR and NMR of all infants. Most infant mortality associated with "all risks" births (81% **or** 137.5/169.6) was neonatal and among "no risk" births (67% **or** 1 – 1.8/5.4) was post-neonatal (Table 5.11).

Table 5.11
Infant and neonatal mortality rates by risk category for infants with **"all risks"** (LBW, PTB, and IUGR) and **"no risk"** (NBW, term, and no IUGR) - Detroit (1984 to 1988)

Gestational Age (weeks)	Infant Deaths/Births		IMR/1,000 Live births	Neonatal Deaths/Births		NMR/1,000 Live births
All risks	127	749	169.6	103	749	137.5
No risk	370	67,922	5.4	119	67,922	1.8

NEIGHBORHOOD DEMOGRAPHIC CHARACTERISTICS

Four population (ecological) demographic characteristics of the individual neighborhoods within the City of Detroit were included in this study: percent of blacks in the neighborhood, percent of population less than 15 years old, percent of population 65 years old and older, and median age of mothers of infants in the study population (Table 5.12). The percent of blacks in the population ranged from a low of 10% to a high of 99%. The percent of population less than 15 years old ranged from 3% to 33% and the percent of population 65 years old and older ranged from 5% to 31%. The median maternal age ranged from a low of 22 years to a high of 29 years.

Table 5.12
Selected demographic characteristics for selected neighborhoods – Detroit, Michigan (1990)
(See Appendix F for listing of all neighborhoods)

Five neighborhoods with the highest % black population		**Demographic Characteristic**			
Code	**Geographic Unit**	**% Black**	**% ≤ 15 years old**	**% ≥ 65 years old**	**Median Age of Mothers**
32	Tireman	98.96	23.97	15.93	23
30	Winterhalter	98.77	23.41	14.54	23
31	Durfee	98.32	22.27	17.43	23
5	Bagley	98.00	18.04	13.72	25
21	Harmony Village	97.93	23.95	9.60	23
Five neighborhoods with the lowest % black population		**Demographic Characteristic**			
Code	**Geographic Unit**	**% Black**	**% ≤ 15 years old**	**% ≥ 65 years old**	**Median Age of Mothers**
44	Delray-Springwells	10.34	27.23	10.75	23
35	Chadsey	13.88	26.85	13.42	24
45	Clark Park	14.65	25.87	10.45	23
1	Redford	42.22	22.35	10.71	26
14	Finney	45.63	24.90	12.59	26
0	City of Detroit	75.55	24.66	12.23	24.00

(Source: 1990 US Census)

NEIGHBORHOOD ECONOMIC CHARACTERISTICS

There were six population (ecological) economic characteristics evaluated in this study: percent of homes with at least one car, median household income, percent of households with family income greater than 150% of the federal poverty level, percent of population without high school education, percent female head of household, and median years of maternal education (Table 5.13). The percent of homes with at least one car ranged from a low of 0.9% to a high of 44%. The median household income ranged from $8,438 to $46,111 and the percent of homes with family income more than 150% above the federal poverty level ranged from a low of 34% to a high of 89%. The percent of the adult population without a high school education ranged from 65% to 86% and the percent of homes with female head of household varied from 6% to 42%. The lowest median years of maternal education were 11 years with a maximum of 14 years.

Table 5.13
Selected economic characteristics for selected neighborhoods – Detroit, Michigan (1990)
(See Appendix G for listing of all neighborhoods)

Five neighborhoods with the highest % female head of house		**Economic Characteristic***					
Code	**Geographic Unit**	**% car**	**MHI**	**%APL**	**%<HS**	**%FHH**	**MYME**
42	Mack	21.77	9,885	34.79	74.08	42.12	11
15	Connor	28.26	16,873	48.83	70.47	41.50	12
16	Airport	35.36	11,855	40.79	71.84	41.29	12
21	Harmony Village	36.35	19,968	56.98	69.65	39.19	12
39	Chene	26.70	10,141	32.28	76.11	38.69	12
Five neighborhoods with the lowest % female head of house		**Economic Characteristic***					
Code	**Geographic Unit**	**% car**	**MHI**	**%APL**	**%<HS**	**%FHH**	**MYME**
47	Central Business District	0.86	20,815	51.03	78.87	6.27	12
48	Indian Village	16.72	24,372	74.37	84.18	8.76	13
38	University	2.12	8,438	34.15	80.22	10.48	12
6	Palmer Park	15.70	46,111	88.92	86.10	14.03	14
27	Rouge	39.77	26,907	77.38	64.54	17.44	12
0	City of Detroit	30.12	17,348	56.86	71.49	30.28	12

***Economic variables: % car** = Percent homes with at least one car, **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%<HS** = Percent of adult population without high school education, **%FHH** = Percent female head of household, **MYME** = Median years of maternal education (Source: MYME from birth certificates, all others 1990 US Census)

NEIGHBORHOOD ENVIRONMENTAL CHARACTERISTICS

Five population (ecological) environmental neighborhood characteristics were assessed in this study: percent vacant housing, percent of population renting a home, median property value, percent crowding, and percent housing constructed before 1940 (Table 5.14). The percent vacant housing ranged from a low of 3% to a high of 30%. The variation in percent of population renting a home was from 13% to 75%. The median property value ranged from a low of $15,000 to a high of $132,244. The percent crowding varied from 1% to 14% and percent housing constructed before 1940 from 0.8% to 53%.

TABLE 5.14
Selected Environmental Characteristic for selected neighborhoods – Detroit, Michigan (1990)
(See Appendix H for listing of all neighborhoods)

Five neighborhoods with the highest % vacant housing		**Environmental Characteristic***				
Code	**Geographic Unit**	**%VH**	**%RO**	**MPV**	**%CR**	**%<1940**
47	Central Business District	29.71	68.82	132,244	3.82	0.86
37	Jeffries	28.76	56.72	20,420	3.62	14.49
38	University	22.90	75.20	41,169	6.80	2.12
42	Mack	16.78	54.53	18,353	8.30	21.77
49	East-Riverside	14.65	44.24	25,288	5.47	30.58
Five neighborhoods with the lowest % vacant housing		**Environmental Characteristic***				
Code	**Geographic Unit**	**%VH**	**%RO**	**MPV**	**%CR**	**%<1940**
4	Pembroke	2.92	23.48	34,364	3.74	10.77
5	Bagley	3.10	22.27	38,253	2.94	28.95
27	Rouge	3.43	22.62	26,178	3.54	39.77
9	Pershing	3.72	25.42	23,663	5.61	14.43
23	Rosedale Park	3.75	13.54	47,217	2.37	33.24
0	City of Detroit	8.77	42.96	25,600	4.96	35.79

***Environmental Characteristics:** **%VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value ($1990), **%CR** = Percent crowding, **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

BIVARIATE ANALYSIS OF INDEPENDENT VARIABLES AND BIRTHWEIGHT

This section presents the results of bivariate comparisons of the independent variables and LBW and VLBW. The independent variables include neighborhood of residence at birth, demographic variables, economic variables, and environmental variables. Bivariate analyses are divided into the following categories:

- The association between neighborhood and birthweight
- The association between low-birthweight and very low-birthweight rates and demographic, economic, and environmental variables
- The association between neighborhood and infant and neonatal mortality
- The association between infant and neonatal mortality and demographic, economic, and environmental variables

NEIGHBORHOOD OF RESIDENCE AT TIME OF BIRTH AND BIRTHWEIGHT

For the City of Detroit, the LBW rate (12.7%) and the VLBW rate (2.5%) were both about twice the national average. The LBW rate among the neighborhoods was from 1.2 to 3.3 times the national average. The VLBW rate was not significantly different from the national rate (1.2%) in 11 neighborhoods but is 2 to 3.6 times the national rate in 29 neighborhoods (Table 5.2 on page 98).

DEMOGRAPHIC FACTORS AND BIRTHWEIGHT

The individual demographic variables include race of infant, maternal age, and gender of infant. The ecological demographic variables include percent blacks in the population, percent of population less than 15 years old, and percent of population 65 years of age and older.

Each of the individual demographic variables is associated with LBW (Table 5.15). The LBW rate is greater among black infants than among white infants (odds ratio = 1.9 with 95% C.I. = 1.8, 2.0). The LBW rate is greater among infants of mothers age 35 years and older than among mothers ages 17 to 34 years (odds ratio = 1.2 with 95% C.I. = 1.1, 1.3). Male infants are less likely to be LBW than female infants are (odds ratio = 0.8 with 95% C.I. = 0.8, 0.9).

There is also an association between neighborhood (ecological) demographic characteristics and LBW. The risk of LBW is nearly 50% greater among infants born in neighborhoods whose percent black population is in the third and fourth quartiles (odds ratio = 1.4 with 95% C.I. = 1.3, 1.5) when compared to those born in neighborhoods in the first quartile. LBW is more frequent in infants born in neighborhoods whose percent of population 15 years old and younger is in the third quartile (odds ratio = 0.8 with C.I. = 0.7, 0.9) when compared to those born in neighborhoods in the first quartile. Finally, the LBW rate is greater in neighborhoods whose percent of population 65 years and older is in the middle two quartiles (odds ratio = 0.8 with 95% C.I. = 0.8, 0.9) when compared to neighborhoods in the first quartile.

Table 5.15
Low-birthweight Rate (LBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for demographic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix I for bivariate analysis of all demographic variables)

Variable (I) = Individual (E) = Ecological	Quartile	Births < 2500 gm	Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Race of Infant (I)					
White	-	1,502	19,700	7.6	Reference
Black	-	9,255	64,544	14.3	1.9 (1.8, 2.0)
Maternal age (I)					
17 – 34	-	9,517	75,765	12.6	Reference
≥ 35		736	5,049	14.6	1.2 (1.1, 1.3)
Gender of Infant (I)					
Female	-	5,780	41,736	13.9	Reference
Male	-	5,046	43,529	11.6	0.8 (0.8, 0.9)
Percent of population black (E)*					
≤ 65.01	1st	2,228	22,053	10.1	Reference
> 65.01 to ≤ 86.95	2nd	2,571	21,215	12.1	1.2 (1.1, 1.3)
> 86.95 to ≤ 95.18	3rd	3,011	20,930	14.4	1.4 (1.3, 1.5)
> 95.18	4th	3,018	21,072	14.3	1.4 (1.3, 1.5)
Percent of population ≤ 15 years old (E)*					
≤ 23.28	1st	2,871	21,324	13.5	Reference
> 25.05 to ≤ 27.80	3rd	2,340	21,490	10.9	0.8 (0.8, 0.9)
Percent of population ≥ 65 years old (E)*					
≤ 9.06	1st	2,920	20053	14.6	Reference
> 9.06 to ≤ 10.75	2nd	2,312	19360	11.9	0.8 (0.8, 0.9)
> 10.75 to ≤ 15.50	3rd	2,667	22413	11.9	0.8 (0.8, 0.9)

*(Source: 1990 US Census)

Four of six demographic variables are also associated with VLBW (Table 5.16). Two individual demographic characteristics are associated with VLBW: Blacks infants are more likely to be born VLBW than are white infants (odds ratio = 2.6 with 95% C.I. = 2.2, 2.9) and infants whose gender cannot be determined are more likely to be VLBW than infants whose gender can be determined (odds ratio = 15.8 with 95% C.I. = 3.1, 81.4). Two neighborhood (ecological) variables are also associated with VLBW: The risk of VLBW increases as the percent of blacks in a neighborhood increases and is 60%

greater in the third and fourth quartiles (odds ratio = 1.6 with 95% C.I. = 1.4, 1.9) compared to neighborhoods in the first quartile and the percent of population equal to or less than 15 years old is associated with VLBW when the third quartile is compared to the first quartile (odds ratio = 0.7 with 95% C.I. = 0.7, 0.8).

Table 5.16
Very Low-birthweight Rate (VLBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for demographic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix J for bivariate analysis of all demographic variables)

Variable (I) = Individual (E) = Ecological*	**Quartile**	**Births < 1500 gm**	**Live Births**	**% VLBWR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
Race of Infant (I)					
White	-	228	19,700	1.2	Reference
Black	-	1,906	64,544	3.0	2.6 (2.2, 2.9)
Gender of Infant (I)					
Female	-	1,058	41,736	2.5	Reference
Unknown	-	2	5	40.0	15.8 (3.1, 81.4)
Percent of population black (E)					
≤ 65.01	1st	398	22,053	1.8	Reference
> 65.01 to ≤ 86.95	2nd	500	21,215	2.4	1.3 (1.1, 1.5)
> 86.95 to ≤ 95.18	3rd	620	20,930	3.0	1.6 (1.5, 1.9)
> 95.18	4th	624	21,072	3.0	1.6 (1.4, 1.9)
Percent of population ≤ 15 years old (E)					
≤ 23.28	1st	602	21,324	2.8	Reference
> 25.05 to ≤ 27.80	3rd	448	21,490	2.1	0.7 (0.7, 0.8)

*(Source: 1990 US Census)

ECONOMIC FACTORS AND BIRTHWEIGHT

The neighborhood economic variables evaluated included five ecological variables: percent of homes with at least one car, median household income, percent of households with family income above 150% of the federal poverty level, percent of population without a high school education, and percent of homes with female head of household. The only individual economic variable was years of maternal education.

Each of the economic variables is associated with LBW (Table 5.17). The weakest association is the percent homes with at least one car. This association is only evident when the last quartile is compared to the first quartile (odds ratio = 1.1 with 95% C.I. = 1.1, 1.2). Median household income is associated with LBW and the strongest association is evident when the fourth quartile is compared to the first quartile (odds ratio = 1.5 with 95% C.I. = 1.4, 1.5). The percent of homes with family income above 150% of the federal poverty level is inversely associated with LBW. This association is greatest when the fourth quartile is compared to the first (odds ratio = 1.4 with 95% C.I. = 1.3, 1.5). The percent female head of household in a neighborhood is directly associated with LBW. This association is greatest when the fourth is compared to the first quartile (odds ratio = 1.4 with 95% C.I. = 1.3, 1.4).

Individual educational achievement and neighborhood educational levels both are associated with the LBWR. Maternal years of education is inversely associated with the LBWR with the greatest difference being evident when those without a high school education are compared to those who had additional education after high school (odds ratio = 1.4 with 95% C.I. = 1.3, 1.4). Similarly, the LBWR increases as the percent of adult population in a neighborhood decreases and is greatest when the fourth quartile is compared to the first (odds ratio = 1.3 with 95% C.I. = 1.2, 1.3).

Table 5.17
Low-birthweight Rate (LBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for economic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix K for bivariate analysis of all economic variables)

Neighborhood (I) = Individual (E) = Ecological	**Quartile**	**Births < 2500 gm**	**Live Births**	**% LBWR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
% Car (E)					
≥ 35.36	1st	2,699	22,162	12.2	Reference
< 26.70	4th	2,819	20,696	13.6	1.1 (1.1, 1.2)
MHI (E)					
≥ 25405	1st	2,367	22,330	10.7	Reference
< 25405 to ≥ 17348	2nd	2,641	21,164	12.5	1.2 (1.1, 1.2)
< 17348 to ≥ 12174	3rd	2,866	22,728	12.6	1.2 (1.1, 1.3)
< 12174	4th	2,954	19,048	15.5	1.5 (1.4, 1.5)
%APL (E)					
≥ 66.06	1st	2,446	22,849	10.7	Reference
< 66.06 to ≥ 54.17	2nd	2,708	21,607	12.5	1.2 (1.1, 1.2)
< 54.17 to ≥ 44.73	3rd	2,655	20,918	12.7	1.2 (1.1, 1.3)
< 44.73	4th	3,019	19,896	15.2	1.4 (1.3, 1.5)
%FHH (E)					
≤ 27.09	1st	2,366	22,377	10.6	Reference
> 27.09 to ≤ 33.42	2nd	2,687	21,592	12.4	1.2 (1.1, 1.3)
> 33.42 to ≤ 37.07	3rd	2,803	20,417	13.7	1.3 (1.2, 1.4)
> 37.07	4th	2,972	20,884	14.2	1.4 (1.3, 1.4)
YME (I)					
> 12 years	-	2,366	22,069	10.7	Reference
12 years	-	3,990	32,915	12.1	1.1 (1.1, 1.2)
< 12 years	-	4,361	29,787	14.6	1.4 (1.3, 1.4)
%<HS (E)					
≤ 69.00	1st	2,463	22,290	11.1	Reference
> 69.00 to ≤ 70.67	2nd	2,648	21,185	12.5	1.1 (1.1, 1.2)
> 70.67 to ≤ 74.08	3rd	2,922	21,805	13.4	1.2 (1.2, 1.3)
> 74.08	4th	2,795	19,990	14.0	1.3 (1.2, 1.3)

***Economic variables: % Car** = Percent homes with at least one car, **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%FHH** = Percent female head of household, **YME** = Years of maternal education, **%<HS** = Percent of adult population without high school education, (Source: YME from birth certificates, all others 1990 US Census)

Four of six economic variables are associated with VLBW (Table 5.18). Median household income is only associated with VLBW when the fourth quartile is compared to the first quartile (odds ratio = 1.4 with 95% C.I. = 1.3, 1.6). Another measure of population income, the percent of population above 150% of the federal poverty level, is associated with VLBW when the second (odds ratio = 1.2 with 95% C.I. = 1.1, 1.3) and

Table 5.18
Very Low-birthweight Rate (VLBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for economic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix L for bivariate analysis of all economic variables)

Neighborhood (I) = Individual (E) = Ecological*	**Quartile**	**Births <1500 gm**	**Live Births**	**% LBWR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
MHI (E)					
≥ 25405	1st	481	22,330	2.2	Reference
< 12174	4th	591	19048	3.1	1.4 (1.3, 1.6)
%APL (E)					
≥ 66.06	1st	497	22,849	2.2	Reference
< 66.06 to ≥ 54.17	2nd	557	21,607	2.6	1.2 (1.1, 1.3)
< 44.73	4th	603	19,896	3.0	1.4 (1.2, 1.6)
%FHH (E)					
≤ 27.09	1st	429	22,377	1.9	Reference
> 27.09 to ≤ 33.42	2nd	576	21,592	2.7	1.4 (1.2, 1.6)
> 33.42 to ≤ 37.07	3rd	555	20,417	2.7	1.4 (1.3, 1.6)
> 37.07	4th	582	20,884	2.8	1.5 (1.3, 1.7)
%<HS (E)					
≤ 69.00	1st	489	22,290	2.2	Reference
> 69.00 to ≤ 70.67	2nd	572	21,805	2.6	1.2 (1.1, 1.4)
> 74.08	4th	561	19,990	2.8	1.3 (1.1, 1.5)

***Economic variables:** **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%FHH** = Percent female head of household, **%<HS** = Percent of adult population without high school education, (Source: YME from birth certificates, all others 1990 US Census)

the fourth quartiles (odds ratio = 1.4 with 95% C.I. = 1.2, 1.6) are compared to the first quartile. The percent adult population without an education and VLBW are also associated. VLBW is more frequent in mothers from neighborhoods whose percent of adult population without a high school education is in the third (odds ratio = 1.2 with 95% C.I. = 1.1, 1.4) and fourth quartiles (odds ratio = 1.3 with 95% C.I. = 1.1, 1.5) when compared to those in the first quartile. Finally, the percent female head of household in a neighborhood was associated with the mother's risk of VLBW. There is little difference in the strength of the association when the second, third, and fourth quartiles are compared to the first quartile. However, the association is greatest when the fourth quartile is compared to the first quartile (odds ratio = 1.5 with 95% C.I. = 1.3, 1.7).

ENVIRONMENTAL FACTORS AND BIRTHWEIGHT

The environmental variables evaluated include percent vacant housing, percent renter occupied housing, median property value, percent crowding, and percent housing constructed before 1940. LBW (Table 5.19) and VLBW (Table 5.20) are both associated with four of five environmental factors.

There is an association between LBW and the percent vacant housing when the second (OR = 1.2 with 95% C.I. = 1.1, 1.3), third (OR = 1.3 with 95% C.I. = 1.2, 1.4), and fourth (OR = 1.3 with 95% C.I. = 1.3, 1.4) quartiles are compared to the first quartile.

The association between the percent renter occupancy and LBW is present for the second (OR = 1.1 with 95% C.I. = 1.1, 1.2), third (OR = 1.3 with 95% C.I. = 1.2, 1.3), and fourth quartiles (OR = 1.3 with 95% C.I. = 1.3, 1.4) when compared to the first quartile. The LBW rate is associated with median neighborhood property value when the second (OR = 1.2 with 95% C.I. = 1.1, 1.2), third (OR = 1.3 with 95% C.I. = 1.2, 1.3), and fourth (OR = 1.2 with 95% C.I. = 1.1, 1.3) quartiles are compared to the first quartile. The percent housing constructed before 1940 is associated with LBW when the second (OR = 1.1

with 95% C.I. = 1.1, 1.2), third (OR = 1.2 with 95% C.I. = 1.1, 1.3), and fourth (OR = 1.2 with 95% C.I. = 1.2, 1.3) quartiles are compared to the first quartile.

Table 5.19

Low-birthweight Rate (LBWR) per 100 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for environmental variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix M for bivariate analysis of all environmental variables)

Variable*	Quartile	Births < 2500 gm	Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
%VH					
≤ 5.50	1st	2,526	23,814	10.6	Reference
> 5.50 to ≤ 7.16	2nd	2,434	19,151	12.7	1.2 (1.1, 1.3)
> 7.16 to ≤ 10.30	3rd	2,992	21,649	13.8	1.3 (1.2, 1.4)
> 10.30	4th	2,876	20,656	13.9	1.3 (1.2, 1.4)
%RO					
≤ 30.93	1st	2,331	21,598	10.8	Reference
> 30.93 to ≤ 40.77	2nd	2,627	21,503	12.2	1.1 (1.1, 1.2)
> 40.77 to ≤ 51.88	3rd	2,970	21,971	13.5	1.3 (1.2, 1.3)
> 51.88	4th	2,900	20,198	14.4	1.3 (1.3, 1.4)
MPV					
> 27565	1st	2,234	20,444	10.9	Reference
> 23977 to ≤ 27565	2nd	2,499	19,551	12.8	1.2 (1.1, 1.2)
> 17251 to ≤ 23977	3rd	3,229	23,559	13.7	1.3 (1.2, 1.3)
≤ 17251	4th	2,866	21,716	13.2	1.2 (1.1, 1.3)
%<1940					
≤ 16.64	1st	2,449	21,833	11.2	Reference
> 16.64 to ≤ 34.12	2nd	2,952	23,796	12.4	1.1 (1.1, 1.2)
> 34.12 to ≤ 52.04	3rd	2,610	19,411	13.5	1.2 (1.1, 1.3)
> 52.04	4th	2,817	20,230	13.9	1.2 (1.2, 1.3)

***Environmental Characteristics: %VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value ($1990), **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

The same environmental variables are associated with VLBW (Table 5.20). VLBW is associated with the percent vacant housing. This association is present for the second (OR = 1.2 with 95% C.I. = 1.1, 1.4), third (OR = 1.3 with 95% C.I. = 1.1, 1.4), and fourth (OR = 1.3 with 95% C.I. = 1.1, 1.4) quartiles when compared to the first quartile. The percent renter occupancy is associated with VLBW when the fourth quartile is compared to the first quartile (OR = 1.3 with 95% C.I. = 1.1, 1.4). Median property value is associated with VLBW when the second (OR = 1.2 with 95% C.I. = 1.1, 1.4) and third (OR = 1.3 with 95% C.I. = 1.1, 1.4) quartiles are compared to the first quartile. Finally, the percent housing constructed before 1940 is associated with VLBW when the fourth and first quartiles are compared (OR = 1.2 with 95% C.I. = 1.2, 1.3).

Table 5.20

Very Low-birthweight Rate (VLBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for environmental variables reaching statistical significance - Detroit, Michigan (1984 –1988) (See Appendix N for bivariate analysis of all environmental variables)

Variable*	Quartile	Births < 1500 gm	Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
%VH					
≤ 5.50	1st	508	23,814	2.1	Reference
> 5.50 to ≤ 7.16	2nd	497	19,151	2.6	1.2 (1.1, 1.4)
> 7.16 to ≤ 10.30	3rd	577	21,649	2.7	1.3 (1.1, 1.4)
> 10.30	4th	560	20,656	2.7	1.3 (1.1, 1.4)
%RO					
≤ 30.93	1st	473	21,598	2.2	Reference
> 51.88	4th	560	20,198	2.8	1.3 (1.1, 1.4)
MPV					
> 27565	1st	444	20,444	2.2	Reference
> 23977 to ≤ 27565	2nd	521	19,551	2.7	1.2 (1.1, 1.4)
> 17251 to ≤ 23977	3rd	646	23,559	2.7	1.3 (1.1, 1.4)
%<1940					
≤ 16.64	1st	493	21,833	2.3	Reference
> 52.04	4th	552	20,230	2.7	1.2 (1.1, 1.4)

***Environmental Characteristics:** **%VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value ($1990), **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

BIVARIATE ANALYSIS OF INDEPENDENT VARIABLES AND MORTALITY

This section presents the results of bivariate comparisons of independent variables and the infant mortality rate (IMR) and neonatal mortality rate (NMR). These include neighborhood of residence at birth, demographic variables, economic variables, and environmental variables.

NEIGHBORHOOD OF RESIDENCE AND MORTALITY

The overall IMR (15/1,000 live births) and NMR (8/1,000 live births) were respectively 1.5 and 1.3 times the national IMR (10/1,000 live births) and NMR (7/1,000 live births). The lowest IMR were not significantly different than the national IMR but the lowest NMR were significantly lower than the national NMR. The IMR and NMR of more than half of the neighborhoods were not significantly different than the national IMR and NMR. However, the highest IMRs and NMRs among the neighborhoods were more than twice the national rates during the study (Table 5.2 on page 98).

DEMOGRAPHIC FACTORS AND MORTALITY

The neighborhood (ecological) demographic variables evaluated included percent blacks in the population, percent of population less than 15 years old, percent of population 65 years of age and older. Individual demographic characteristics included race, maternal age, and gender.

Infant mortality is associated with three of the six demographic variables: race, gender, and percent of black population in the neighborhood of maternal residence (Table 5.21). The race of an infant is associated with infant mortality. However, this association is only evident when black infants are compared to white infants (OR = 1.5 with 95% C.I. = 1.3, 1.7). Male infant mortality is greater than female infant mortality (OR = 1.4 with 95% C.I. = 1.2, 1.5) and infants whose gender cannot be determined have much greater infant mortality than female infants do (OR = 63.6 with 95% C.I. = 17.0, 237.5). The percent black population in a neighborhood is associated with infant mortality when the third (OR = 1.4 with 95% C.I. = 1.2, 1.6) and fourth (OR = 1.3 with 95% C.I. = 1.1, 1.5) are compared to the first quartile.

TABLE 5.21
Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for demographic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix O for bivariate analysis of all demographic variables)

Variable (I) = Individual (E) = Ecological*	**Quartile**	**Infant Deaths**	**Live Births**	**IMR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
Race of Infant (I)					
White	-	218	19,700	11.1	Reference
Black	-	1,047	64,544	16.2	1.5 (1.3, 1.7)
Gender of Infant (I)					
Female	-	525	41,736	12.6	Reference
Male	-	746	43,529	17.1	1.4 (1.2, 1.5)
Unknown	-	4	5	800.0	63.6 (17.0, 237.5)
Percent of population black (E)					
≤ 65.01	1st	279	22,053	12.7	Reference
> 86.95 to ≤ 95.18	3rd	359	20,930	17.2	1.4 (1.2, 1.6)
> 95.18	4th	332	21,072	15.8	1.3 (1.1, 1.5)

*(Source: 1990 US Census)

The NMR is only associated with two demographic variables: race and gender (Table 5.22). Black infants (OR = 1.6 with 95% C.I. = 1.3, 1.9) and American Indians (OR = 3.2 with 95% C.I. = 1.2, 8.6) both have a greater risk of neonatal mortality when compared to white infants. The NMR is greater in male infants (OR = 1.3 with 95% C.I. = 1.2, 1.6) and infants whose sex cannot be determined (OR = 106.0 with 95% C.I. = 28.3, 396.6) when compared to female infants.

Table 5.22
Neonatal Mortality Rate (NMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) demographic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix P for bivariate analysis of all demographic variables)

Variable (I) = Individual (E) = Ecological	**Quartile**	**Neonatal Deaths**	**Live Births**	**NMR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
Race of Infant (I)					
White	-	122	19,700	6.2	Reference
Black	-	629	64,544	9.8	1.6 (1.3, 1.9)
American Indian	-	4	205	19.5	3.2 (1.2, 8.6)
Gender of Infant (I)					
Female	-	315	41,736	7.6	Reference
Male	-	440	43,529	10.1	1.3 (1.2, 1.6)
Unknown	-	4	5	800.0	106.0 (28.3, 396.6)

ECONOMIC FACTORS AND MORTALITY

The neighborhood economic variables evaluated were percent of homes with at least one car, median household income, households with family income above 150% of the federal poverty level, percent of population without a high school education, and percent of homes with female head of household. The years of maternal education was the only individual-level economic variable that was evaluated.

Infant mortality is associated with five of six economic variables (Table 5.23). Median household income is inversely associated with infant mortality when the third (OR = 1.2 with 95% C.I. = 1.1, 1.5) and fourth (OR = 1.5 with 95% C.I. = 1.3, 1.8) quartiles are

Table 5.23
Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for economic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix Q for bivariate analysis of all economic variables)

Neighborhood (I) = Individual (E) = Ecological*	**Quartile**	**Infant Deaths**	**Live Births**	**IMR**	**Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)**
MHI (E)					
≥ 25405	1st	275	22,330	12.3	Reference
< 17348 to ≥ 12174	3rd	345	22,728	15.2	1.2 (1.1, 1.5)
< 12174	4th	359	19,048	18.9	1.5 (1.3, 1.8)
%APL (E)					
≥ 66.06	1st	279	22,849	12.2	Reference
< 54.17 to ≥ 44.73	3rd	316	20,918	15.1	1.2 (1.1, 1.5)
< 44.73	4th	365	19,896	18.4	1.5 (1.3, 1.8)
%FHH (E)					
≤ 27.09	1st	286	22,377	12.8	Reference
> 33.42 to ≤ 37.07	3rd	337	20,417	16.5	1.3 (1.1, 1.5)
YME (I)					
> 12 years	-	249	22,069	11.3	Reference
12 years	-	463	32,915	14.1	1.3 (1.1, 1.5)
< 12 years	-	521	29,787	17.5	1.6 (1.3, 1.8)
%<HS (E)					
≤ 69.00	1st	305	22,290	13.7	Reference
> 74.08	4th	354	19,990	17.7	1.3 (1.1, 1.5)

***Economic variables:** **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%FHH** = Percent female head of household, **YME** = Years of maternal education, **%<HS** = Percent of adult population without high school education, (Source: YME from birth certificates, all others 1990 US Census)

compared to the first quartile. Infant mortality is inversely associated with percent of households above 150% of the federal poverty level when the third (OR = 1.2 with 95% C.I. = 1.1, 1.5) and fourth (OR = 1.5 with 95% C.I. = 1.3, 1.8) quartiles are compared to the first quartile. Infant mortality is associated with the percent female head of household when the fourth quartile is compared to the first quartile (OR = 1.3 with 95% C.I. = 1.1, 1.5). Maternal education is associated with infant mortality when mothers with a high school education (OR = 1.3 with 95% C.I. = 1.1, 1.5) and mothers who have not completed high school (OR = 1.6 with 95% C.I. = 1.3, 1.8) are compared to mothers who have education beyond high school. Finally, the percent of adult population without a high school education is associated with infant mortality when the fourth quartile is compared to the first (OR = 1.3 with 95% C.I. = 1.1, 1.5).

Neonatal mortality is associated with three of six economic variables: neighborhood median household income, percent of neighborhood households above 150% of the federal poverty level, and maternal education (Table 5.24). Median household income is associated with neonatal mortality when the fourth and first quartiles are compared (OR =

Table 5.24
Neonatal Mortality Rate (NMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for economic variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix R for bivariate analysis of all economic variables)

Neighborhood (I) = Individual (E) = Ecological*	Quartile	Neonatal Deaths	Live Births	NMR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
MHI (E)					
≥ 25405	1st	168	22,330	7.5	Reference
< 12174	4th	202	19,048	10.6	1.4 (1.2, 1.7)
%APL (E)					
≥ 66.06	1st	172	22,849	7.5	Reference
< 44.73	4th	211	19,896	10.6	1.4 (1.2, 1.7)
YME					
> 12 years	-	158	22,069	7.2	Reference
< 12 years	-	277	29,787	9.3	1.3 (1.1, 1.2)

***Economic variables:** **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **YME** = Years of maternal education, (Source: of YME is the birth certificate, all others 1990 US Census)

1.4 with 95% C.I. = 1.2, 1.7). The percent of homes with family income less than 150% of the federal poverty level is associated neonatal mortality when the fourth and first quartiles are compared (OR = 1.4 with 95% C.I. = 1.2, 1.7). Finally, maternal education is associated with neonatal mortality when mothers who have not completed high school are compared to those who have education beyond high school (OR = 1.3 with 95% C.I. = 1.1, 1.2).

ENVIRONMENTAL FACTORS AND MORTALITY

The environmental variables evaluated were percent vacant housing, percent renter occupied housing, median property value, percent crowding, and percent housing constructed before 1940.

Infant mortality is associated with four of five environmental variables (Table 5.25). The association with percent vacant housing is evident when the third (odds ratio = 1.4 with 95% C.I. = 1.2, 1.7) and fourth (odds ratio = 1.5 with 95% C.I. = 1.2, 1.7) quartiles are compared to the first quartile. Infant mortality and the percent renter occupancy are associated when the third (odds ratio = 1.4 with 95% C.I. = 1.2, 1.6) and fourth (odds ratio = 1.4 with 95% C.I. = 1.2, 1.7) quartiles are compared to the first quartile. Median property value and infant mortality are associated when the second (odds ratio = 1.2 with 95% C.I. = 1.1, 1.4) and fourth (odds ratio = 1.3 with 95% C.I. = 1.1, 1.6) quartiles are compared to the first quartile. Finally, infant mortality is only associated with the percent housing constructed before 1940 when the fourth and first quartiles are compared (odds ratio = 1.2 with 95% C.I. = 1.1, 1.4).

TABLE 5.25
Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for environmental variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix S for bivariate analysis of all economic variables)

Variable*	Quartile	Infant Deaths	Live Births	IMR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
%VH					
≤ 5.50	1st	281	23,814	11.8	Reference
> 7.16 to ≤ 10.30	3rd	363	21,649	16.8	1.4 (1.2, 1.7)
> 10.30	4th	354	20,656	17.1	1.5 (1.2, 1.7)
%RO					
≤ 30.93	1st	258	21,598	12.0	Reference
> 40.77 to ≤ 51.88	3rd	361	21,971	16.4	1.4 (1.2, 1.6)
> 51.88	4th	345	20,198	17.1	1.4 (1.2, 1.7)
MPV					
> 27565	1st	257	20,444	12.6	Reference
> 23977 to ≤ 27565	2nd	657	43,110	15.2	1.2 (1.1, 1.4)
≤ 17251	4th	361	21,716	16.6	1.3 (1.1, 1.6)
%<1940					
≤ 16.64	1st	305	21,833	14.0	Reference
> 52.04	4th	349	20,230	17.3	1.2 (1.1, 1.4)

***Environmental Characteristics: %VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value ($1990), **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

The only environmental variable associated with neonatal mortality is percent crowding (Table 5.26). This association is only seen when the second quartile is compared to the first (odds ratio = 1.3 with 95% C.I. = 1.1, 1.6).

Table 5.26
Neonatal Mortality Rate (NMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for environmental variables reaching statistical significance - Detroit, Michigan (1984 –1988)
(See Appendix T for bivariate analysis of all economic variables)

Variable*	Quartile	Neonatal Deaths	Live Births	NMR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
%Crowding					
≤ 4.66	1st	184	23,719	7.8	Reference
> 4.66 to ≤ 5.80	2nd	203	20,109	10.1	1.3 (1.1, 1.6)

***Environmental Characteristic: % Crowding** = Percent of homes with more than one person per room, (Source 1990 US Census)

ESTIMATION RESULTS

This section is divided into six categories of estimation:

- Number of NICU admissions, lengths of stay (days), and bed demand (beds per 1,000 live births) per neighborhood for infants with a high probability of admission (HPA).
- Number of NICU admissions, lengths of stay (days), and bed demand (beds per 1,000 live births) per neighborhood for infants with a low probability of admission (LPA).
- Number of NICU admissions, lengths of stay (days), and bed demand (beds per 1,000 live births) per neighborhood for all infants assigned to NICU admission (Total).
- Inpatient NICU hospitalization cost ($US, 1988) per neighborhood for high probability admissions (HPA).
- Inpatient NICU hospitalization cost ($US, 1988) per neighborhood for low probability admissions (LPA).
- Inpatient NICU hospitalization cost ($US, 1988) per neighborhood for all infants assigned to NICU (Total).

NICU ADMISSIONS, LOS, AND BED DEMAND: HPA

The percent of LBW and PTB infants with a high probability of admission (HPA) to a NICU is 6.7% overall and ranges from 4.4% to 11.0% among the neighborhoods. The estimated average length of stay for these admissions in the City of Detroit is 24.9 days, ranging from a low of 20.2 days to a high of 29.9 days among the neighborhoods of the city. The estimated demand for HPA NICU beds in Detroit is 4.6 per 1,000 live births and varies from 2.6 to 7.5 per 1,000 live births among the neighborhoods (Tables 5.27).

Table 5.27

Estimated average length of stay (ALOS), estimated number of NICU admissions (all high probability admits – HPA: preterm infants ≤ 34 weeks gestation or ≤ 2000 grams at birth), total known live births, NICU beds per day, and NICU beds per 1000 live births per year - in order of increasing bed demand per 1000 live births, and estimated NICU bed demand* per neighborhood for the City of Detroit between 1984 and 1988

Code	Geographic unit	HPA ALOS	HPA NICU admits	Total live births	HPA NICU beds/day	HPA NICU beds per 1000 live births/year
27	Rouge	24.76	64	1,653	0.87	2.63
45	Clark Park	21.88	77	1,756	0.92	2.63
1	Redford	23.14	66	1,513	0.84	2.77
44	Delray-Springwells	20.18	125	2,450	1.38	2.82
13	Denby	22.08	81	1,653	0.98	2.96
14	Finney	24.10	131	2,787	1.73	3.10
6	Palmer Park	25.49	29	618	0.41	3.28
24	Brightmoor	23.88	118	2,291	1.54	3.37
10	Grant	21.69	40	703	0.48	3.38
35	Chadsey	24.54	102	1,989	1.37	3.45
17	Davison	23.28	110	1,898	1.40	3.70
11	Mt. Olivet	24.32	141	2,525	1.88	3.72
4	Pembroke	23.60	81	1,321	1.05	3.96
7	State Fair	23.42	102	1,598	1.31	4.10
12	Burbank	24.13	165	2,657	2.18	4.11
2	Evergreen	24.89	171	2,837	2.33	4.11
48	Indian Village	29.86	13	256	0.21	4.15
26	Cody	24.51	128	2,046	1.72	4.20
23	Rosedale Park	24.61	81	1,294	1.09	4.22
47	Central Business District	27.98	9	162	0.14	4.26
22	Cerveny	24.17	109	1,685	1.44	4.28
46	Lafayette	23.51	29	424	0.37	4.41
49	East-Riverside	22.66	64	900	0.79	4.41

	HPA ALOS	HPA NICU admits	Total live births	HPA NICU beds/day	HPA NICU beds per 1000 live births/year
***Estimation procedure**	**A**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	24.93	5741	85,270	78.42	4.60

* The average length of stay (ALOS) of each infant was assigned based on birthweight and national birthweight-specific ALOS (Schwartz, 1989).

(Continued on next page)

Table 5.27 (continued)

Estimated average length of stay (ALOS), estimated number of NICU admissions (all high probability admits – HPA: preterm infants ≤ 34 weeks gestation or ≤ 2000 grams at birth), total known live births, NICU beds per day, and NICU beds per 1000 live births per year - in order of increasing bed demand per 1000 live births, and estimated NICU bed demand* per neighborhood for the City of Detroit between 1984 and 1988

Code	Geographic unit	HPA ALOS	HPA NICU admits	Total live births	HPA NICU beds/day	HPA NICU beds per 1000 live births/year
9	Pershing	27.17	96	1,609	1.43	4.44
25	Grandmont	26.31	84	1,346	1.21	4.50
43	Boynton	26.66	41	657	0.60	4.56
28	Brooks	26.03	218	3,354	3.11	4.64
38	University	22.98	72	971	0.91	4.67
5	Bagley	26.32	86	1,317	1.24	4.71
15	Connor	25.28	253	3,667	3.50	4.78
29	Mackenzie	25.10	230	3,308	3.16	4.78
21	Harmony Village	23.97	244	3,223	3.20	4.97
32	Tireman	24.36	172	2,252	2.30	5.10
3	Greenfield	27.04	157	2,260	2.33	5.15
39	Chene	24.41	126	1,633	1.69	5.16
16	Airport	27.31	159	2,193	2.38	5.42
40	Kettering-Butzel	25.12	209	2,588	2.88	5.56
41	St. Jean	26.26	163	2,108	2.35	5.56
37	Jeffries	23.80	50	586	0.65	5.56
8	Nolan	25.33	186	2,286	2.58	5.65
31	Durfee	27.19	188	2,431	2.80	5.76
42	Mack	25.68	202	2,362	2.84	6.02
30	Winterhalter	26.13	138	1,634	1.98	6.05
36	Condon	26.64	109	1,251	1.59	6.36
33	Rosa Parks	24.86	221	2,354	3.01	6.39
20	McNichols	27.85	109	1,124	1.66	7.40
34	Central	24.65	192	1,740	2.59	7.45

	HPA ALOS	HPA NICU admits	Total live births	HPA NICU beds/day	HPA NICU beds per 1000 live births/year
***Estimation procedure**	**A**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	24.93	5741	85,270	78.42	4.60

* The average length of stay (ALOS) of each infant was assigned based on birthweight and national birthweight-specific ALOS (Schwartz, 1989).

NICU ADMISSION, LOS, AND BED DEMAND: LPA

By definition, the percent of infants with a low probability of admission assigned to NICU for the city and all neighborhoods was 4.3%. Likewise, all LPA infants were assigned a length of stay of 7.6 days. Therefore, the NICU bed demand was a function of the number of births of infants weighing less than 2,000 grams in each neighborhood. The estimated demand resulting from these assumptions is a demand of 0.8 NICU beds per 1,000 live births for the city and ranged from 0.8 to 0.9 beds per 1,000 live births among the neighborhoods (Table 5.28).

NICU ADMISSION, LOS, AND BED DEMAND: TOTAL

The total percent of infants assigned to NICU overall is 10.4% and ranges from 8.5 % to 14.9% among the neighborhoods. The estimated total average length of NICU stay for the City of Detroit is 23.8 days, ranging from a low of 20.6 days to a high of 28.1 days among the neighborhoods of the city. The total estimated demand for NICU beds is 5.4 per 1,000 live births and varies from 3.5 to 8.3 per 1,000 live births among the neighborhoods (Table 5.28).

Table 5.28
Estimated average length of stay (AOLS), estimated low probability NICU admissions - LPA (4.3% of infants who are more than 2,000 grams and more than 34 weeks gestation), actual number of total live births, estimated NICU beds occupied by LPA infants each day, estimated LPA NICU bed demand* per 1,000 live births in order of increasing bed demand per 1000 live births (Total demand = LPA + HPA demand)

	Geographic unit	LPA ALOS	LPA NICU admits	Total live births	LPA NICU beds/day	LPA (total) NICU beds/1000 live births
45	Clark Park	7.6	72	1,756	0.30	0.85 (3.48)
27	Rouge	7.6	68	1,653	0.28	0.86 (3.49)
1	Redford	7.6	62	1,513	0.26	0.85 (3.62)
44	Delray-Springwells	7.6	100	2,450	0.42	0.85 (3.67)
13	Denby	7.6	68	1,653	0.28	0.86 (3.82)
14	Finney	7.6	114	2,787	0.47	0.85 (3.96)
6	Palmer Park	7.6	25	618	0.10	0.84 (4.13)
24	Brightmoor	7.6	93	2,291	0.39	0.85 (4.22)
10	Grant	7.6	29	703	0.12	0.86 (4.23)
35	Chadsey	7.6	81	1,989	0.34	0.85 (4.30)
17	Davison	7.6	77	1,898	0.32	0.84 (4.54)
11	Mt. Olivet	7.6	103	2,525	0.43	0.85 (4.57)
4	Pembroke	7.6	53	1,321	0.22	0.84 (4.81)
7	State Fair	7.6	64	1,598	0.27	0.83 (4.93)
12	Burbank	7.6	107	2,657	0.45	0.84 (4.95)
2	Evergreen	7.6	115	2,837	0.48	0.84 (4.95)
48	Indian Village	7.6	10	256	0.04	0.81 (5.00)
26	Cody	7.6	82	2,046	0.34	0.83 (5.04)
23	Rosedale Park	7.6	52	1,294	0.22	0.84 (5.06)
47	Central Business District	7.6	7	162	0.03	0.90 (5.10)
22	Cerveny	7.6	68	1,685	0.28	0.84 (5.12)
46	Lafayette	7.6	17	424	0.07	0.83 (5.24)
49	East-Riverside	7.6	36	900	0.15	0.83 (5.25)

	LPA ALOS	LPA NICU admits	Total live births	LPA NICU beds/day	LPA (Total) NICU beds per 1000 live births/year
***Estimation procedure**	**a**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	7.6	3,420	85,270	14.24	0.84 (5.44)

*Average length of stay (ALOS) for LPA infants assigned to NICU admission (4.3% of infants > 34 weeks gestation and > 2,500 grams) was based on ALOS of normal birthweight infant admitted to NICU in a large metropolitan (Boston) population (Gray, 1996).

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Table 5.28 (continued)

Estimated average length of stay (AOLS), estimated low probability NICU admissions - LPA (4.3% of infants who are more than 2,000 grams and more than 34 weeks gestation), actual number of total live births, estimated NICU beds occupied by LPA infants each day, estimated LPA NICU bed demand* per 1,000 live births in order of increasing bed demand per 1000 live births (Total demand = LPA + HPA demand)

Code	Geographic unit	LPA ALOS	LPA NICU admits	Total live births	LPA NICU beds/day	LPA (total) NICU beds/1000 live births
9	Pershing	7.6	65	1,609	0.27	0.84 (5.28)
25	Grandmont	7.6	54	1,346	0.22	0.84 (5.34)
43	Boynton	7.6	26	657	0.11	0.82 (5.40)
28	Brooks	7.6	135	3,354	0.56	0.84 (5.47)
38	University	7.6	39	971	0.16	0.84 (5.50)
5	Bagley	7.6	53	1,317	0.22	0.84 (5.55)
15	Connor	7.6	147	3,667	0.61	0.83 (5.61)
29	Mackenzie	7.6	132	3,308	0.55	0.83 (5.61)
21	Harmony Village	7.6	128	3,223	0.53	0.83 (5.80)
32	Tireman	7.6	89	2,252	0.37	0.82 (5.92)
3	Greenfield	7.6	90	2,260	0.37	0.83 (5.98)
39	Chene	7.6	65	1,633	0.27	0.83 (5.99)
16	Airport	7.6	87	2,193	0.36	0.83 (6.26)
40	Kettering-Butzel	7.6	102	2,588	0.42	0.82 (6.38)
37	Jeffries	7.6	23	586	0.10	0.82 (6.38)
41	St. Jean	7.6	84	2,108	0.35	0.83 (6.39)
8	Nolan	7.6	90	2,286	0.37	0.82 (6.47)
31	Durfee	7.6	96	2,431	0.40	0.82 (6.59)
42	Mack	7.6	93	2,362	0.39	0.82 (6.84)
30	Winterhalter	7.6	64	1,634	0.27	0.82 (6.87)
36	Condon	7.6	49	1,251	0.20	0.82 (7.18)
33	Rosa Parks	7.6	92	2,354	0.38	0.81 (7.21)
20	McNichols	7.6	44	1,124	0.18	0.82 (8.21)
34	Central	7.6	67	1,740	0.28	0.80 (8.25)

	LPA ALOS	LPA NICU admits	Total live births	LPA NICU beds/day	LPA (Total) NICU beds per 1000 live births/year
***Estimation procedure**	**a**	**b**	**c**	**a*b/1,825**	**a*b/1,825/(c/5)*1,000**
Example (City of Detroit)	24.93	5741	85,270	78.42	0.84 (5.44)

*Average length of stay (ALOS) for LPA infants assigned to NICU admission (4.3% of infants > 34 weeks gestation and > 2,500 grams) was based on ALOS of normal birthweight infant admitted to NICU in a large metropolitan (Boston) population (Gray, 1996).

Inpatient NICU hospitalization cost: HPA

The estimated average cost per hospital stay for HPA NICU admissions in the City of Detroit is $12,930 ($US, 1988), as determined by assigning the birthweight-specific cost to all births in Detroit (See table 4.1 on page 88). This ranges from $10,273 to $15,976 among the neighborhoods within the city. The cost added to each birth, including those not admitted to NICU (incremental cost), within the city is $784 during the study period and varies from a low of $428 to $1,355 in the individual neighborhoods (Table 5.29).

Inpatient NICU hospitalization cost: LPA

By definition, estimated average cost per hospital stay for infants with a low probability of NICU admission in the City of Detroit and all neighborhoods is $11,504 ($US, 1988). As a result of these assumptions, the cost added to each birth (incremental cost - includes those not admitted to NICU) within the city is $433. The incremental cost ranges from $413 to $446 per neighborhood during the study period (the variance is related to the difference in the proportion of LPA infants in each neighborhood) (Table 5.30).

Inpatient NICU hospitalization cost: Total

The estimated total incremental cost per birth of NICU care for the city of Detroit is $1255 and ranged from $871 to $1774. The contribution of normal birthweight NICU care represented a relatively small portion of the incremental cost for NICU care (24.4%) for the City of Detroit (5.30)

Table 5.29

Estimated* average cost (1988 $US) per stay, estimated number of NICU admissions (all high probability admits – HPA: preterm infants ≤ 34 weeks gestation or ≤ 2000 grams at birth), total known live births, estimated incremental cost per year, and estimated incremental cost per birth by neighborhood in order of estimated increasing incremental cost for the City of Detroit 1984 through 1988.

Code	Geographic unit	HPA ACOS ($)	HPA NICU admits	Total live births	Incremental HPA Cost/year (million $)	Incremental HPA Cost/birth ($)
45	Clark Park	10,470	77	1,756	0.15	428
27	Rouge	12,741	64	1,653	0.15	466
44	Delray-Springwells	10,273	125	2,450	0.24	488
1	Redford	12,091	66	1,513	0.15	496
13	Denby	11,230	81	1,653	0.17	515
14	Finney	12,309	131	2,787	0.30	545
10	Grant	10,407	40	703	0.08	551
24	Brightmoor	12,410	118	2,291	0.28	602
35	Chadsey	12,738	29	1,989	0.25	616
6	Palmer Park	13,864	102	618	0.08	617
17	Davison	11,641	110	1,898	0.24	633
11	Mt. Olivet	12,759	141	2,525	0.34	672
2	Evergreen	12,598	171	2,837	0.41	716
4	Pembroke	12,475	81	1,321	0.19	721
12	Burbank	12,495	165	2,657	0.39	731
7	State Fair	12,241	102	1,598	0.24	736
47	Central Business District	14,148	9	162	0.02	746
49	East-Riverside	11,266	109	900	0.14	750
22	Cerveny	12,373	64	1,685	0.25	754
23	Rosedale Park	12,898	81	1,294	0.20	762
26	Cody	13,012	13	2,046	0.31	769
46	Lafayette	11,982	128	424	0.07	770
48	Indian Village	15,976	29	256	0.04	775

	HPA ACOS ($)	HPA NICU admits	Total live births	Incremental HPA Cost/year (million $)	Incremental HPA Cost/birth ($)
***Estimation procedure**	a	b	c	$(a*b-718*b)/5/10^3$	(a*b-718*b)/c
Example (City of Detroit)	12,930	5,741	85,270	14.02	822

* The average cost per stay is based on birthweight of each infant and national average birthweight-specific cost (Schwartz, 1989). NICU admit is based on the expectation that infants of these HPA weights and gestational ages will require NICU care. The incremental increase cost is obtained by subtracting the average estimated cost for normal birthweight infants who are not admitted to a NICU ($718 – Schwartz, 1989) from the total estimated cost of NICU admissions.

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Table 5.29 (continued)

Estimated* average cost (1988 $US) per stay, estimated number of NICU admissions (all high probability admits – HPA: preterm infants ≤ 34 weeks gestation or ≤ 2000 grams at birth), total known live births, estimated incremental cost per year, and estimated incremental cost per birth by neighborhood in order of estimated increasing incremental cost for the City of Detroit 1984 through 1988.

Code	Geographic unit	HPA ACOS ($)	HPA NICU admits	Total live births	Incremental HPA Cost/year (million $)	Incremental HPA Cost/birth ($)
9	Pershing	13,967	96	1,609	0.25	790
25	Grandmont	13,815	84	1,346	0.22	817
38	University	11,846	72	971	0.16	825
5	Bagley	13,482	86	1,317	0.22	833
28	Brooks	13,547	218	3,354	0.56	834
43	Boynton	14,187	41	657	0.11	841
15	Connor	12,950	253	3,667	0.62	844
29	Mackenzie	13,013	230	3,308	0.57	855
21	Harmony Village	12,458	244	3,223	0.57	889
39	Chene	12,291	126	1,633	0.29	893
32	Tireman	12,636	172	2,252	0.41	910
3	Greenfield	14,431	157	2,260	0.43	953
37	Jeffries	11,990	50	586	0.11	962
8	Nolan	12,980	186	2,286	0.46	998
16	Airport	14,481	159	2,193	0.44	998
41	St. Jean	13,660	163	2,108	0.42	1,001
40	Kettering-Butzel	13,455	209	2,588	0.53	1,029
31	Durfee	14,278	188	2,431	0.51	1,049
42	Mack	13,186	202	2,362	0.50	1,066
30	Winterhalter	13,963	138	1,634	0.37	1,119
33	Rosa Parks	12,777	221	2,354	0.53	1,132
36	Condon	13,937	109	1,251	0.29	1,152
34	Central	12,955	192	1,740	0.47	1,350
20	McNichols	14,691	109	1,124	0.30	1,355

	HPA ACOS ($)	HPA NICU admits	Total live births	Incremental HPA Cost/year (million $)	Incremental HPA Cost/birth ($)
***Estimation procedure**	a	b	c	$(a*b-718*b)/5/10^3$	(a*b-718*b)/c
Example (City of Detroit)	12,930	5,741	85,270	14.02	822

* The average cost per stay is based on birthweight of each infant and national average birthweight-specific cost (Schwartz, 1989). NICU admit is based on the expectation that infants of these HPA weights and gestational ages will require NICU care. The incremental increase cost is obtained by subtracting the average estimated cost for normal birthweight infants who are not admitted to a NICU ($718 – Schwartz, 1989) from the total estimated cost of NICU admissions.

Table 5.30

Estimated* average cost (1988 $ US) per stay, estimated number of low probability NICU admisions – LPA (4.3% of infants who are more than 2,000 grams and more than 34 weeks gestation), estimated incremental cost per year, and estimated incremental cost per birth by neighborhood in order of estimated increasing incremental cost for the City of Detroit 1984 through 1988. (Total = LPA + HPA cost)

Code	Geographic unit	LPA ACOS ($)	LPA NICU admits	Total live births	Incremental LPA Cost/year (million $)	Incremental LPA (total) Cost/birth ($)
45	Clark Park	11,504	72	1,756	0.16	443 (871)
27	Rouge	11,504	68	1,653	0.15	446 (911)
44	Delray-Springwells	11,504	100	2,450	0.22	440 (928)
1	Redford	11,504	62	1,513	0.13	444 (940)
13	Denby	11,230	68	1,653	0.15	441 (956)
14	Finney	11,504	114	2,787	0.25	442 (987)
10	Grant	11,504	29	703	0.06	437 (989)
24	Brightmoor	11,504	93	2,291	0.20	440 (1,042)
35	Chadsey	11,504	81	1,989	0.18	440 (1,056)
6	Palmer Park	11,504	25	618	0.05	442 (1,059)
17	Davison	11,504	77	1,898	0.17	437 (1,070)
11	Mt. Olivet	11,230	103	2,525	0.22	438 (1,110)
2	Evergreen	11,504	115	2,837	0.25	436 (1,152)
4	Pembroke	11,504	53	1,321	0.12	435 (1,156)
12	Burbank	11,504	107	2,657	0.23	435 (1,166)
7	State Fair	11,504	64	1,598	0.14	434 (1,170)
47	Central Business District	11,504	36	162	0.08	431 (1,181)
49	East-Riverside	11,504	7	900	0.01	438 (1,184)
22	Cerveny	11,504	68	1,685	0.15	434 (1,188)
23	Rosedale Park	11,504	52	1,294	0.11	435 (1,197)
26	Cody	11,504	17	2,046	0.04	432 (1,202)
46	Lafayette	11,504	82	424	0.18	435 (1,204)
48	Indian Village	11,504	10	256	0.02	440 (1,215)

	LPA ACOS ($)	LPA NICU admits	Total live births	Incremental LPA Cost/year (million $)	Incremental LPA (total) Cost/birth ($)
*Estimation procedure	a	b	c	$(a*b-718*b)/5/10^3$	(a*b-718*b)/c
Example (City of Detroit)	11,504	3420	85,270	7.38	433 (1,255)

*Average cost of stay based on average cost for normal birthweight infants admitted to NICU in a large metropolitan (Boston) population (Gray, 1996). The cost per year is obtained by multiplying average cost per stay by the number of NICU admits and dividing by 5. The incremental increase cost per birth is obtained by dividing the total cost by the total number of births in the neighborhood and subtracting the national average charge for normal birthweight infants discharged to home ($718 – Schwartz, 1989).

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Table 5.30 (continued)

Estimated* average cost (1988 $ US) per stay, estimated number of low probability NICU admissions – LPA (4.3% of infants who are more than 2,000 grams and more than 34 weeks gestation), estimated incremental cost per year, and estimated incremental cost per birth by neighborhood in order of estimated increasing incremental cost for the City of Detroit 1984 through 1988. (Total = LPA + HPA cost)

Code	Geographic unit	LPA ACOS ($)	LPA NICU admits	Total live births	Incremental LPA Cost/year (million $)	Incremental LPA (total) Cost/birth ($)
9	Pershing	11,504	65	1,609	0.14	436 (1,227)
25	Grandmont	11,504	54	1,346	0.12	435 (1,252)
38	University	11,504	39	971	0.08	429 (1,255)
5	Bagley	11,504	53	1,317	0.11	434 (1,267)
28	Brooks	11,230	135	3,354	0.29	434 (1,267)
43	Boynton	11,504	26	657	0.06	435 (1,275)
15	Connor	11,504	147	3,667	0.32	432 (1,276)
29	Mackenzie	11,504	132	3,308	0.29	432 (1,286)
21	Harmony Village	11,504	128	3,223	0.28	429 (1,317)
39	Chene	11,504	65	1,633	0.14	428 (1,321)
32	Tireman	11,504	89	2,252	0.19	428 (1,339)
3	Greenfield	11,230	90	2,260	0.20	432 (1,384)
37	Jeffries	11,504	23	586	0.05	424 (1,386)
8	Nolan	11,504	90	2,286	0.19	426 (1,424)
16	Airport	11,504	87	2,193	0.19	430 (1,428)
41	St. Jean	11,504	84	2,108	0.18	428 (1,429)
40	Kettering-Butzel	11,504	102	2,588	0.22	426 (1,455)
31	Durfee	11,504	96	2,431	0.21	428 (1,477)
42	Mack	11,504	93	2,362	0.20	424 (1,490)
30	Winterhalter	11,504	64	1,634	0.14	425 (1,543)
33	Rosa Parks	11,504	92	2,354	0.20	420 (1,552)
36	Condon	11,504	49	1,251	0.11	423 (1,575)
34	Central	11,504	67	1,740	0.14	413 (1,763)
20	McNichols	11,504	44	1,124	0.09	419 (1,774)

	LPA ACOS ($)	LPA NICU admits	Total live births	Incremental LPA Cost/year (million $)	Incremental HPA (total) Cost/birth ($)
***Estimation procedure**	a	b	c	$(a*b-718*b)/5/10^3$	(a*b-718*b)/c
Example (City of Detroit)	12,930	5,741	85,270	14.02	822 (1,255)

*Average cost of stay based on average cost for normal birthweight infants admitted to NICU in a large metropolitan (Boston) population (Gray, 1996). The cost per year is obtained by multiplying average cost per stay by the number of NICU admits and dividing by 5. The incremental increase cost per birth is obtained by dividing the total cost by the total number of births in the neighborhood and subtracting the national average charge for normal birthweight infants discharged to home ($718 – Schwartz, 1989).

MODELING RESULTS

This section presents the mathematical models. There are two linear regression models developed from the data: One linear regression model demonstrates the relationship between birthweight and the neighborhood demand for NICU beds and the second demonstrates the relationship between birthweight and NICU cost. Additional models demonstrating the effect of day-to-day variation in NICU demand, the effect of inter-facility cooperation, and selected "what if" scenarios are also presented. The modeling results are divided into the following categories:

- The relation between the very low-birthweight rate and NICU demand
- The relation between the very low-birthweight rate and NICU cost
- Modeling the effect of NICU size, daily variation in NICU bed demand, and inter-facility cooperation
- Modeling the effect of tolerance for "no bed available days"
- Modeling "what if" scenarios

LINEAR REGRESSION MODEL FOR BIRTHWEIGHT AND NICU DEMAND

The relationship between the very low-birthweight rate and NICU demand yields a linear regression model that predicted 93% (R^2 = 0.93 and adjusted R^2 = 0.93 with a standard error of 0.32) of the variance in the data. The constant and VLBW coefficients were significant with relatively narrow confidence intervals (Table 5.31).

Table 5.31
Model Predicting Demand for NICU Beds

	Beta Unstandardized Coefficients	Standard Error	Beta Standardized Coefficients	T	Significance	95% Confidence Interval
Constant	1.5	.2	-	8.7	< .001	1.1 - 1.8
VLBW	1.6	.1	.96	23.8	< .001	1.4 - 1.7

LINEAR REGRESSION MODEL FOR BIRTHWEIGHT AND NICU COST

The relationship between the very low-birthweight rate and incremental NICU cost yields a linear regression model that predicted 94% (R^2= 0.94 and adjusted R^2 = 0.94 with a standard error of 51) of the variability. The constant and VLBW coefficients were both significant with relatively narrow confidence intervals (Table 5.32).

Table 5.32
Model Predicting Incremental NICU Cost

	Beta Unstandardized Coefficients	Standard Error	Beta Standardized Coefficients	T	Significance	95% Confidence Interval
Constant	526.3	27.6	-	19.1	< .001	470.8 - 581.8
VLBW	291.5	10.7	.97	27.2	< .001	269.9 - 313.0

MODELING THE EFFECT OF NICU SIZE, DAILY VARIATION IN NICU BED DEMAND, AND INTERFACILITY COOPERATION

A supply of 110 beds in a single NICU would be adequate to meet the estimated mean daily demand of 93 beds 96% of the time. However, 110 beds become progressively less sufficient as these beds are divided among an increasing number of units (Table 5.33). A single NICU of 120 beds would meet the demand for NICU beds 100% of the days but distributing the beds among four hospitals would require 148 NICU beds to meet the demand. Inter-facility cooperation among all units would have an effect similar to decreasing the number of NICUs depending on the degree of cooperation.

Table 5.33
The Effect of NICU Size on the Adequacy of the Bed Supply

	Distribution of 110 beds*			
	1 unit	**2 units**	**5 units**	**10 units**
Days (%) bed supply is inadequate	4	10	18	23
Days (%) bed supply is adequate	96	90	82	77

* The number of beds in Detroit was divided among 1, 2, 5, and 10 NICUs. The proportion of days that the supply would be adequate was then determined by assuming that the day-to-day variation is described by a *poisson*. (See the Statistical Models section of Chapter 4 – Methods)

MODELING THE EFFECT OF VARYING TOLERANCE FOR "NO BED AVAILABLE DAYS"

The number of beds per NICU needed to meet the demand decreases steadily as the tolerance for "no bed available days" increases. Starting with a tolerance of 24 days per 100, a 42% increase in NICU beds (44 beds) would be necessary to eliminate "no bed available days". Simultaneously, the mean percent occupancy would decrease from 88% to 62% (Table 5.34).

Table 5.34
The Effect of Tolerance for "No Bed Available Days" on Adequacy of the Bed Supply

	Percent of days "no bed available" is tolerated*			
	24	**14**	**4**	**0**
Total NICU beds	104	112	132	148
Annual occupancy (%)	88	82	70	62

* The average daily NICU bed demand in Detroit was assumed to be 93 beds. It was also assumed that the available NICU beds were divided among four NICUs. The proportion of days that a given number of NICU beds would be adequate was then determined by assuming that the day-to-day variation is described by a *poisson*. (See the Statistical Models section of Chapter 4 – Methods)

MODELING "WHAT IF" SCENARIOS

The modeling of theoretical scenarios on the demand for NICU beds revealed a progressive decrease in bed demand and decrease incremental increase in cost as the very low-birthweight rate "decreased" (Table 5.35).

Table 5.35
The effect* of various scenarios on bed occupancy and incremental cost per birth in order of decreasing incremental cost

Scenario	% VLBW	Mean NICU bed demand	HPA Incremental Increase in cost/birth ($)
Existing circumstance	2.5	93.0	822
Only resuscitate infants weighing ≥ 600 grams	2.2	74.7	770
Increase all birthweights 100 grams	2.2	70.5	726
Only resuscitate infants weighing ≥ 700 grams	2.0	71.2	721
Only resuscitate infants weighing ≥ 750 grams	1.9	69.3	693

* The potential effect of each scenario on the "VLBW (treated) rate" of Detroit was determined and the VLBW rate of each scenario was entered in the linear regression models (demand and cost) in order to estimate the effect on demand and cost in the City of Detroit.

VALIDATION OF DATABASE AND MODELS

The steps taken to assess the impact of the limitations of the study are divided into the following categories:

- Analysis of excluded records
- Comparison of study results with "known" demand in other populations

ANALYSIS OF EXCLUDED RECORDS

The mean birthweight was 3126 grams before and 3142 grams after records with missing census tracts and census tracts outside the city of Detroit were eliminated. The percent black was 75% both before and after removal of these records and the percent white was 23% before and after removal of these records. The LBW rate was 12.6% before and

12.7% after removal of excluded records and the VLBW rate was 2.5% before and after removal of the excluded records. The IMR was 15.2 per 1,000 live births before excluded records were removed and 15.0 per 1,000 live births after removal of excluded records. Finally, the neonatal mortality rate was 9.0 per 1,000 live births before and 8.9 per 1,000 live births after the removal of excluded records.

COMPARISON OF DEMAND MODEL WITH OTHER STUDIES OF NICU BED DEMAND

Entering the VLBW rate of three populations, the model yielded the following results:

- Entering the VLBW rate of 2.51% in Detroit, the model predicts a demand of 5.5 (95% C.I. = 4.8, 6.1) NICU beds per 1,000 live births. The actual daily bed demand during the five years of the study was 5.6 NICU beds per 1,000 live births according to responses to the Michigan Department of Community Annual Hospital Statistical Questionnaires between 1984 and 1988.

- Entering the VLBW rate of 0.84% in the Northern Neonatal Network, Regional Health Authority of England (NNN, 1991), the model predicts a demand of 2.8 (95% C.I. = 2.4, 3.3) NICU beds per 1,000 live births. This is compared to the demand of 3.5 NICU beds per 1,000 live births estimated by researchers in the NNN.

- Entering the VLBW rate of 0.89% in the Trent Regional Health Authority of England (TRHA, 1990 to 1992), the model predicts a demand of 2.9 (95% C.I. = 2.4, 3.4) NICU beds per 1,000 live births. This is compared to the demand of 3.6 NICU beds per 1,000 live births estimated by researchers in the TRA.

- Entering the VLBW rate of 0.61% in the Utah in 1977, the model predicts a demand of 2.4 (95% C.I. = 1.0, 2.9) NICU beds per 1,000 live births. This is compared to a demand of 2.0 NICU beds per 1,000 live births estimated by researchers in Utah.

SUMMARY

The presentation of the analyses of data is now complete. This included the following: descriptive statistics, bivariate analysis, results of estimation procedures, modeling results, and validation of the database and models. The next chapter will review the implications of these results.

CHAPTER 6

DISCUSSION

The heterogeneity of IMRs, NMRs, LBW rates, VLBW rates, and measures of poverty among neighborhoods within the City of Detroit is evident from the results presented in the previous chapter. Neighborhood demand for NICU beds varied greatly among neighborhoods within Detroit and was closely related to the neighborhood VLBW rate. An exploration of the results, the related implications and the potential limitations of the databases and methods are presented in this chapter. The discussion proceeds in the following order: descriptive statistics, bivariate analyses, results of estimation procedures, modeling results, limitations of the database and estimation procedures, and steps taken to assess the impact of the limitations of the study.

DESCRIPTIVE STATISTICS

This section presents a discussion of the neighborhood characteristics and birthweight-specific infant and neonatal mortalities. The neighborhood characteristics include birthweight, gestational age, demographic variables, economic variables, and environmental variables. It is clear from the descriptive statistics that Detroit is not a homogenous population and the burden of poverty and LBW is not evenly distributed in the population. The discussion of descriptive statistics is divided into the following categories:

- Neighborhood demographic, economic, and environmental characteristics
- Neighborhood birthweight and gestational-age distribution
- Neighborhood-specific low-birthweight and very low-birthweight rates
- Neighborhood-specific infant and neonatal mortality rates
- Birthweight and gestational age-specific infant and neonatal mortality rates
- Interaction between birthweight, gestational age, and infant and neonatal mortality

NEIGHBORHOOD DEMOGRAPHIC, ECONOMIC, AND ENVIRONMENTAL CHARACTERISTICS

Community socioeconomic characteristics appear to affect LBW and VLBW rates.[85], [86] Therefore, it may be possible to predict the NICU demand of an urban population from such characteristics. Low community income, percent of residents under 18 years old, percent housing units with more than one person per room, and percent African-American residents have been associated with LBW. Detroit's population is predominantly young, poor, black, and under-educated, but the demographic, economic, and environmental characteristics of the City of Detroit as a whole do not reflect the variation of these characteristics among its constituent neighborhoods.

Organizing the City of Detroit into neighborhoods with similar socioeconomic characteristics facilitates health-care planning and the evaluation of the factors associated with LBW and VLBW. The variation in levels of poverty among the neighborhoods of Detroit is reflected in the variability of LBW and VLBW rates among the neighborhoods.

Demographic, economic, and environmental characteristics have been used to predict the distribution of LBW in an urban population and, theoretically, could be used in a model to predict NICU demand.[85] It is also possible that demographic, economic, and environmental factors may affect the demand for NICU beds by prolonging the length of NICU stay. For example, the NICU LOS would be extended if physicians are hesitant to discharge LBW infants to "impoverished" home environments.

NEIGHBORHOOD BIRTHWEIGHT AND GESTATIONAL-AGE DISTRIBUTION

Neonatal morbidity is associated with LBW and PTB as has been noted earlier. Therefore, the search for variables to incorporate in a model to predict the demand for NICU beds in a population could reasonably include the birthweight distribution or gestational-age distribution of the population in question. However, both of these distributions have limitations.

The birthweight distribution of a population is a crude measure of newborn birthweight because there are actually two separate and discrete distributions hidden within this overall distribution: One distribution consists predominantly of term infants and the other distribution consists primarily of preterm infants.[16] Preterm births make a greater contribution to NICU demand but represent only a small proportion of the total distribution. Thus, the variation in NICU bed demand generated by preterm infants is, in effect, "masked" by the large contribution term infants make to the total distribution.

A model to predict NICU bed demand incorporating the gestational-age distribution of a population could "capture" more preterm births. However, gestational-age assessment is highly inaccurate, especially in VLBW infants.[87] This inaccuracy is reflected in the lack of variation in mean and median gestational-ages among Detroit neighborhoods. Therefore, it is unlikely that the gestational-age distribution of a population will be predictive in a model of NICU bed demand.

Gestational-age was used to identify infants (those ≤ 34 weeks) who had a high probability of NICU admission in Detroit. The inaccuracies of gestational-age assessment could have influenced the outcome of the present study. However, the limitations of gestational-age assessment are minimal among infants who reach 34 weeks gestation and among infants who weigh more than 1500 grams. As a result, using gestational-age of 34 weeks and less to assign infants to NICU admission status should not adversely affect the validity of the models presented in this study.

NEIGHBORHOOD-SPECIFIC LOW-BIRTHWEIGHT AND VERY LOW-BIRTHWEIGHT RATES

The neighborhood-specific LBW and VLBW rates in Detroit reveal substantial variation that is hidden in the neighborhood-specific birthweight and gestational-age distributions. The standard of medical care dictates that infants with LBW in general and VLBW in particular receive NICU care. Thus, LBW and VLBW rates in a population must be closely related to NICU bed demand.

Unfavorable LBW and VLBW rates both increase neighborhood-specific demand for NICU care, although the VLBW rate is probably a better predictor of NICU demand because VLBW infants have much greater lengths of stay than infants between 1,500 and 2,500 grams. The VLBW rate of a population must be closely related to the demand for

NICU care since, as noted earlier, the VLBW rate of an industrialized country is the best predictor of the NMR. It is, therefore, reasonable to assume the VLBW rate of a population may be the best predictor of NICU bed demand.

NEIGHBORHOOD-SPECIFIC INFANT AND NEONATAL MORTALITY RATES

The high LBW and VLBW rates would be expected to increase NMRs and IMRs. Thanks to advances in NICU care, the IMRs and NMRS in most neighborhoods were not significantly different than the national rates. Among the neighborhoods of Detroit, only 49% (23/47) had IMRs, and only 27% (12/47) had NMRs, greater than the national average. This was true even though the LBW rate of each neighborhood and the VLBW rate of 77% (36/47) of the neighborhoods were significantly greater than the national rates. This reflects the benefit of NICU care as has been noted previously.[38]

In 1960, prior to advances in NICU care and the deliberate regionalization of perinatal care, the national NMR was 18.4 per 1,000 live births.[88] Applying the 1960 birthweight-specific NMR to the Detroit birthweight distribution, the NMR would have been 30.6 per 1,000 live births; in light of this, there would have been 2,608 neonatal deaths during the study period but the actual number of neonatal deaths was only 758 by comparison. This 71% reduction in predicted neonatal mortality reflects the birthweight-specific improvement in neonatal survival resulting from NICU care. However, there is a "mixed blessing" in the improved birthweight-specific survival: Neonatal and infant mortality are reduced but NICU bed demand and the subsequent burden of morbidity associated with LBW and PTB are increased. Thus, the demand for NICU beds is increased as the NMR is reduced in the presence of high LBW rates. As a result, one would expect the NMR to be an important variable in any model predicting the demand for NICU beds. However, the NMR did not contribute to either of the models presented in this thesis. It is possible that the models would have demonstrated the impact of lower neonatal mortality rates if they had incorporated the mean days of birthweight-specific survival among infants who died before leaving the NICU.

BIRTHWEIGHT AND GESTATIONAL AGE-SPECIFIC MORTALITY RATES

LBW and PTB are associated with increased neonatal and infant mortality. As would be expected, infant mortality and neonatal mortality in Detroit increased as the birthweight decreased. Similarly, with the exception of infants > 43 weeks gestation, infant mortality and neonatal mortality decreased with increasing gestational age. These findings emphasize the well-established association between infant mortality and PTB.

BIRTHWEIGHT, GESTATIONAL-AGE, AND INFANT AND NEONATAL MORTALITY

The interaction between birthweight and gestational age is demonstrated by the high mortality rates among infants who are both preterm and low-birthweight (IMR = 114, NMR = 8.8) compared to infants who are term and normal-birthweight (IMR = 5.6, NMR = 0.2). This interaction is even more evident among infants who are preterm and small for gestational-age (IMR = 145, NMR = 11.8) compared to infants who are term and not small for gestational-age (IMR = 5.5, NMR = 0.2). These findings support previous evidence demonstrating additional variability in perinatal mortality that is unexplained by birthweight alone.[21]

Gestational-age also appears to affect the timing of infant mortality (Table 6.1). Infant mortality among term infants is predominantly post-neonatal but neonatal mortality accounts for most infant mortality among preterm infants. This has not been described previously. It would be interesting to see if this is a "local phenomenon" or reflects the national experience. It seems likely that most preterm infants succumb in early life from respiratory complications caused by immaturity of the lungs while term infants die later in life from problems including congenital disorders that interfere with intrauterine and post-neonatal development, sudden infant death syndrome, infectious diseases, accidental deaths, neglect, and physical abuse.

Table 6.1
Percent neonatal and post-neonatal mortality for term and preterm births by risk category

Term Infant	**Risk Category**			
Mortality	**LBW**	**NBW**	**IUGR**	**Non-IUGR**
Neonatal	48%	32%	44%	33%
Post neonatal	52%	68%	56%	67%
PTB Infant	**Risk Category**			
Mortality	**LBW**	**NBW**	**IUGR**	**Non-IUGR**
Neonatal	78%	45%	81%	74%
Post neonatal	12%	55%	19%	26%

BIVARIATE ANALYSES

This section presents a discussion of the bivariate comparisons of independent variables and the LBW, VLBW, neonatal mortality, and infant mortality rates. The variables include neighborhood of residence at birth, demographic variables, socioeconomic variables, and environmental variables. It is important to remember that the associations between birthweight and neighborhood demographic, economic, and environmental characteristics are subject to ecological fallacy and confounding. These associations, even if proven to be true at the neighborhood level, may not be true at the individual level. In addition, each of these variables may be confounded by factors such as maternal smoking, alcohol consumption, complications of pregnancy and delivery, parity, maternal height, pre-pregnancy weight, and individual demographic characteristics. Still, the well-known association between poverty and LBW and IMR is evident. Thus, the variation in poverty among neighborhoods in Detroit finds expression in the heterogeneous LBW rates and IMRs among neighborhoods. The discussion of the associations identified between poverty and LBW rates and IMRs is divided into the following categories:

- The association between neighborhood of maternal residence and the LBW and VLBW rate
- The association between low-birthweight and very low-birthweight rates and demographic, economic, and environmental variables
- The association between neighborhood of maternal residence at time of birth and infant and neonatal mortality
- The association between infant and neonatal mortality and demographic, economic, and environmental variables

NEIGHBORHOOD OF RESIDENCE AT TIME OF BIRTH AND BIRTHWEIGHT

A study of the distribution of LBW rates in Chicago revealed greater variation among 77 neighborhoods (0.1% to 19.5%) than seen among neighborhoods in Detroit.[85] However, the variation in LBW rates in both Chicago and Detroit were concealed in the citywide LBW rates. Clearly, the burden of high LBW rates is not evenly distributed in these and most urban populations. Thus, analysis of neighborhood-specific LBW rates in urban populations can facilitate public health planning.

BIRTHWEIGHT AND DEMOGRAPHIC, ECONOMIC, AND ENVIRONMENTAL VARIABLES

Little has been published about the association between LBW and neighborhood level demographic, economic, and environmental variables. The relationship between poverty and LBW is typically expressed as a function of individual risk factors. However, access to health-care, social support, and psychological support must be closely related to the availability of resources within the community of maternal residence. LBW and the associated demand for NICU beds may be less common in high-risk pregnancies among women residing in neighborhoods with greater social advantage.[85],[89]

Demographic factors and birthweight

Individual level demographic characteristics including race, gender, and maternal age have been identified as "risk factors" for LBW. The association of LBW and female gender is related to the lower weight of females compared to males as they approach term. The increased risk of LBW and VLBW associated with infants of unknown gender reflects the difficulty in determining the gender of extremely LBW infants. This study confirms the increased risk of LBW among black infants, infants of unknown gender, female infants, and maternal age $\geq$ 35 years. Still, race is the only demographic characteristic that has consistently been associated with LBW when controlled for confounding variables.[34]

Interestingly, maternal age and female gender are not risk factors for VLBW but the risk of VLBW (O.R. = 2.6 with 95% C.I.= 2.2, 2.9) associated with black race is actually greater than the risk of LBW (O.R. = 1.9 with 95% C.I.= 1.8, 2.0). The lack of association between maternal age and birthweight has been described previously, as has the association between black race and birthweight. It is likely that older maternal age, like female gender, decreases birthweight only modestly and, as a result, does not affect the VLBW rate. The greater effect of black race as a risk factor for VLBW may be the result of confounding. However, it may also reflect a genetically based difference in the risk of VLBW as has been suggested previously for LBW risk.[90]

In this study some neighborhood demographic characteristics were associated with LBW or both VLBW and LBW. The risk of LBW and VLBW were both increased among neighborhoods when the percent of black population was more than 65% or the percent of population 15 years of age and younger was less than 25%. The risk of LBW but not VLBW was greater when the percent of population 65 years and older increased. The association between percent young population and LBW has been identified previously but segregation actually appeared to decrease the risk of LBW and percent population 65 years and older was not associated with LBW.[85] Still, it must be remembered that the associations identified in the current study are not adjusted for confounding variables.

Economic factors and birthweight

The association of LBW and VLBW with median household income, percent of households below the federal poverty level, percent female head of household, and percent of population without a high school education suggest that poverty at the community level contributes to the risk of LBW and VLBW. Again, the associations identified in this study may be confounded or mediated by factors such as maternal smoking, alcohol consumption, complications of pregnancy and delivery, parity, gestational weight gain, maternal height, pre-pregnancy weight, and community demographic characteristics. However, there is evidence that neighborhood poverty is associated with LBW even when adjusted for potentially confounding individual level variables.[85],[89]

Environmental factors and birthweight

The association of LBW and VLBW with multiple environmental variables suggests that physical surroundings affect birthweight. These bivariate associations may be confounded by individual variables and co-linear with economic variables. However, it has been suggested that the association between LBW and environmental factors persists when adjusted for individual level and economic variables.[85]

NEIGHBORHOOD OF RESIDENCE AND MORTALITY

The benefit of NICU care is evident when the VLBW rate and NMR of each neighborhood are compared. The VLBW rate of 77% (36/47) of the neighborhoods was at least 1.5 times the national average but only 26% (12/47) of the neighborhoods had NMRs above the national average. In the absence of access to NICU care, it is likely that the NMR for the City of Detroit would have been much greater (30.6 per 1,000 live births rather than 8.9 per 1,000 live births, as noted earlier, a 244% difference). Although high VLBW rates do not consistently increase NMRs, they undoubtedly increase the demand for NICU care because the length of stay increases inversely with the weight of surviving infants.[38] Thus, the survival benefit of NICU care is a "mixed blessing" because improved birthweight-specific survival increases NICU demand. Paradoxically, a community with a high VLBW rate and a high NMR may actually have lower NICU demand than one with a high VLBW rate and a low NMR. Therefore, the NMR of a neighborhood (or specific NICU) may contribute to the variation in NICU bed demand among neighborhoods (or NICUs) and may be an important variable in a model predicting NICU bed demand (especially if NMRs continue to improve in the future).

MORTALITY AND DEMOGRAPHIC, ECONOMIC, AND ENVIRONMENTAL VARIABLES

The association between poverty and infant mortality is well established. The effect of poverty on infant mortality (especially neonatal mortality) is usually mediated through birthweight with most infant deaths occurring in LBW infants. However, there has been no exploration of the association between infant mortality and neighborhood level demographic, economic, and environmental variables after adjustment for individual risk factors. In the case of neonatal mortality, one would need to speculate that poverty has an effect on survival that extends beyond the effect on birthweight. This concept is supported by evidence that birthweight-specific mortality rates of LBW black infants are greater when population-specific definitions of "smallness" are used.[91] In the absence of established evidence of adjusted associations between neighborhood level poverty and neonatal mortality, the crude associations identified in the present study support inclusion of the NMR of a population in a model to predict NICU bed demand.

Demographic factors and mortality

Individual demographic variables were associated with IMR, NMR, or both. Infant race is known to be associated with both infant and neonatal mortality.[18] The crude association in this study is consistent and of the same magnitude of other unadjusted associations. The association of infant and neonatal mortality with unknown gender is understandable because these infants usually represent extremely low-birthweight infants. However, the association between male gender and infant and neonatal mortality has not been described previously. Therefore, this association may be a chance occurrence or a confounded association.

Since race may be considered a proxy for poverty, it is possible to speculate that the IMR but not NMR was higher among infants born in neighborhoods with higher concentrations of blacks because of risk factors associated with postnatal death after discharge from the hospital. This is plausible because the NMR in these neighborhoods was not increased in spite of higher VLBW rates. However, it must be remembered that these are crude associations that may not hold up when controlled for confounding.

Economic factors and mortality

The association of infant mortality with multiple economic variables is not surprising given the known association between poverty and LBW. Economic factors appear to have a more limited impact on neonatal mortality because the association is only evident at the highest "exposure" level. It is tempting to posit that poverty poses a threat to the well being of infants after they return to the neighborhood and are exposed to an impoverished environment. However, unless the poverty is extreme, there is little effect on survival during hospitalization immediately after birth. This possibility is supported by evidence that, even when controlled for potential individual confounders, an impoverished neighborhood environment increases the risk of death among adults.[86]

Environmental factors and mortality

The influence of environmental factors on infant and neonatal mortality is similar to that seen with economic factors. This is understandable because poverty is expressed in both economic and environmental terms. All environmental variables except percent crowding were associated with infant mortality at some level of exposure. However, only percent crowding was associated with neonatal mortality (and then only at a single intermediate level of exposure with a relatively low odds ratio). Therefore, the latter association may be chance while the former suggests the possibility of a causal association as discussed for economic variables in the preceding paragraph.

ESTIMATION OF NICU ADMISSIONS, LOS, DEMAND, AND COST

The strength of the models developed from the data is very dependent on the strength of the estimation procedures. The estimation procedure would have been better if it had been possible to link the hospital data from the Michigan Inpatient Database with the remaining data. Still, the rational estimation procedure used in this thesis is theoretically sound and effectively demonstrates the diversity of demand and cost among Detroit neighborhoods. A discussion of the implications of the estimation procedure is divided into the following categories:

- NICU Admission
- NICU Length of Stay
- NICU Bed Demand
- NICU Cost

NICU ADMISSION

The decision to assign only infants ≤ 34 weeks gestation or ≤ 2,000 grams may have underestimated the actual number admitted. It is reasonable to assume that most of these infants would require NICU care and contribute substantially to the demand for NICU beds. However, the *Guidelines for Perinatal Care* suggest that most infants ≤ 2,500 grams (or ≤ 36 weeks gestation) will require NICU care. In defense of the decision to use tighter limits for NICU admission, it seems likely that many of the infants closer to 2,500 grams or 36 weeks would not require extended, if any, NICU care and would contribute little to the overall variation in demand for NICU beds.

The decision to assign 4.3% of all normal birthweight infants (and those > 2,000 grams or > 34 weeks) to NICU care is based on evidence from another urban population. In addition, the illnesses causing NICU admission among normal birthweight infants have not been shown to vary across populations. It should be noted that the contribution these infants make to the NICU admission rate in each neighborhood varied inversely with the LBW rate (the more LBW infants, the fewer NBW infants available for assignment to NICU).

NICU Length of Stay

The decision to assign the length of stay based on national averages may be problematic because it fails to consider the possibility of local differences in NICU utilization. Birthweight-specific length of stay has not been demonstrated to vary much across populations, but the estimates used in this study were based on a large and diverse population (98% of infants born in the United States) and length of stay may be influenced by local health-care utilization patterns and population risks.

NICU Bed Demand

The NICU demand by neighborhood is a direct function of NICU admission and LOS. It is subject to the limitations mentioned for NICU admission and LOS but no additional limitations are evident.

NICU Cost

The estimation of cost is very crude. Defining and determining cost is complex as noted previously. Furthermore, there is wide variation in cost of NICU care among hospitals. The purpose of including the cost was for comparative purposes among neighborhoods. Therefore, it is important that these figures not be interpreted as actual costs.

DISCUSSION OF MODELING RESULTS

This section presents a discussion of the models developed from the data. This includes the association between the VLBW rate and NICU demand, the association between the VLBW rate and cost, modeling the effect of "no bed available days", modeling the effect of NICU size and day-to-day variation in NICU bed demand, and modeling "what if" scenarios. The models presented build on the strengths of previous models and overcome many of the limitations of previous studies. The discussion of the modeling results is presented in the following order:

- The association between the VLBW rate and NICU demand
- The association between the VLBW rate and cost
- Modeling the effect of NICU size and day-to-day variation in NICU bed demand
- Modeling the effect of varying tolerance for "no bed available days"
- Modeling "what if" scenarios

ASSOCIATION BETWEEN THE VLBW RATE AND NICU DEMAND

It is important to remember that the estimates of demand reflect a rational model based on current utilization and the application of national LOS and cost data to Detroit infants. These may not reflect the actual experience in Detroit. Actual NICU admission status was unknown and no effort was made to establish whether or not each infant really required NICU admission and NICU care for each day of the hospital stay in the study on which the length of stay estimates were based.[67] Likewise, no attempt was made to assess the possibility of "back transfer" to basic newborn care once critical care was no longer needed. Demand could be diminished if strict criteria were used to limit admissions, duration of NICU stay, and NICU bed demand. However, this was beyond the scope of this thesis and the estimate of demand reflects a rational estimate of current utilization.

The high correlation between VLBW and NICU demand probably reflects the use of birthweight to assign both of the variables used to predict demand: NICU admission and LOS. However, VLBW infants only accounted for 2.5% (2163) of all births and 50% of those assigned to NICU but the VLBW rate predicted 93% of the variance in demand. This study could be improved substantially if NICU admission status and length of stay could be obtained by directly linking birth certificate data to the Michigan Inpatient Database.

Earlier it was suggested that the NMR of a neighborhood could contribute to NICU bed demand because lower neonatal mortality could potentially lengthen hospital stays if associated with high VLBW rates. However, the NMR did not make a significant contribution to this model. This finding may reflect comparable neonatal mortality rates among NICUs within Detroit. It is also possible that the populations served by these NICUs may overlap and obscure individual variations in the NMR. Future modifications of this model would be necessary if survival rates of VLBW infants rise over time.

In spite of the limitations of the model, it demonstrates substantial variation in demand for NICU beds among the neighborhoods of Detroit. This mirrors the variation in VLBW rates among neighborhoods and emphasizes the key hypotheses of this thesis: The neighborhood should be the geographic area of interest when health-care planning is undertaken in large urban populations. Efforts of health-care planners and public health officials could be facilitated by an awareness of the marked variation in demand generated by unfavorable birthweight distributions within neighborhoods of large cities. Furthermore, it is reasonable to assume that an assessment of the individual risk factors driving LBW and VLBW rates within individual neighborhoods may reveal differing population attributable risks by neighborhood and help focus public health efforts. The addition of individual risk factors to the current birth certificate utilized in Michigan could facilitate this assessment when combined with geocoding of birth certificates. Finally, linking this data to hospital discharge data in the Michigan Inpatient Database would create a powerful database for perinatal research.

ASSOCIATION BETWEEN THE VERY LOW-BIRTHWEIGHT RATE AND COST

The high correlation between VLBW and cost probably reflects the use of birthweight to assign cost (Table 4.1 on page 88). Improving cost estimates is a complex process, beyond the scope of this thesis, and would only reflect the cost of NICU care in this population. Nevertheless, being able to directly obtain the NICU admission status and length of stay would facilitate cost estimation.

A valid model to predict the cost of NICU care by neighborhood would be helpful to public health officials and health-care planners. The savings generated by various effective public health interventions could be assessed more realistically when applied across neighborhoods with varying risks and NICU demand. This model may be too crude for these purposes.

THE EFFECT OF NICU SIZE AND DAY-TO-DAY VARIATION IN NICU BED DEMAND

The statistical element of this model is straightforward and leaves little room for error, but the pragmatic component of this model is more complex. The number of beds required to meet the demand for NICU beds varies substantially from day-to-day because NICU admissions follow a *poisson* distribution. The impact of this variation is less as the size of the NICU providing care increases. The 110 NICU beds in the City of Detroit in 1987 would have been adequate 96% of the days if the NICU care were being coordinated among the four hospitals providing NICU care. However, they were not working cooperatively and the NICU bed supply was "inadequate". Therefore, 20 additional NICU beds were licensed in the City of Detroit in 1988.

According to the Michigan Department of Community Health (MDCH) Annual Hospital Surveys, in 1987 the percent occupancy among the four NICUs in Detroit was 87% and no NICU had an average daily census of less than 15. In 1988 the percent occupancy was 76% and one NICU had an average daily census of less than 15. By 1996 there were seven NICUs in Detroit with 204 NICU beds, the percent occupancy was 68%, and two NICUs had an average daily census of less than 15. Surprisingly, according to MDCH vital statistics, the number of births in the City of Detroit fell from about 20,000 in 1987 to about 17,000 in 1996. In addition, the LBW rate fell from 14.8% in 1987 to 12.8% in 1996 while the VLBW rate fell from 3.5% in 1987 to 2.8% in 1996. The falling number of births, lower LBW rate, lower VLBW rate, and decreasing occupancy suggest that demand didn't increase (and perhaps decreased). Perhaps greater survival among LBW infants has increased demand somewhat, but it seems more likely that efficiency has diminished within the perinatal regions of Detroit (perhaps because of the policies that foster managed care and competition among hospitals). This alone is cause for concern. However, it is intolerable if smaller average daily censuses among NICUs results in increased neonatal mortality among LBW infants in these regions.

The difference between demand for NICU beds and the number of beds required to meet this demand is implicit in the model predicting the day-to-day variation in demand. Determining the demand for NICU beds given current utilization is straightforward. The number of NICU admissions in a population and the length of stay of each admission are used to calculate the total number of NICU bed-days required. Determining the number of NICU beds needed to meet the demand depends on tolerance for days with "no bed available", number of NICUs in the population, distribution of beds among the NICUs, distribution of the demand, and inter-facility cooperation. Implementing policies that promote inter-facility cooperation and reduce the number of NICU beds required to meet demand could prove difficult in an era of managed care and managed competition.

“NO BED AVAILABLE” TOLERANCE

Between 1984 and 1987 there were four neonatal intensive care units with a total of 110 NICU beds. It is estimated that this supply would have been “inadequate” to meet the demand 14% of the days. In fact, and the number of beds divided among these units was increased to 130 in 1988. This supply would only be inadequate 2% of the days if distributed proportionately throughout the city. It is unlikely that most members of our society will tolerate a decrease in the availability of NICU care. However, inter-facility cooperation can help reduce “no bed available” days as noted below.

“What if” scenarios

At first glance it may seem unethical to limit resuscitation efforts to those infants who are below a certain weight. However, few of these extremely low-birthweight infants survive and many of those who do survive have moderate to severe disabilities. Therefore, these scenarios must be considered in light of the need to utilize resources cautiously. Eventually it may be possible to identify infants for whom NICU care is futile.

Although it is possible to model the effect of favorable changes in the VLBW rate of a neighborhood, this may prove difficult to achieve in “real life” because multiple factors are responsible for the LBW and VLBW rate within a population. Therefore, it is unlikely that a single intervention would raise the birthweight of all infants by 100 grams. On the other hand, a multifaceted approach in a community might realistically achieve a significant reduction in the weight of LBW infants.

LIMITATIONS OF THE DATA

The potential for data entry errors is a concern in any study. The potential for this problem in the current study is exemplified by the high rate of duplicate entries (17.1%) and missing census tracts (4.5%). This may be further demonstrated by the fact that a high percentage (27.6%) of the linked death-birth certificate records were missing in the birth residence Census Tract (although these were probably missing because the City of Detroit births were the only ones being geocoded). These errors could affect the results of this study if the effect on neonatal mortality or the very low-birthweight rate was differential (e.g. infants with missing Census Tracts had higher very low-birthweight rates and neonatal mortality rates than infants for whom this data was available). However, the very low-birthweight rate was determined with and without these records and no difference was found. Therefore, it seems unlikely that the results have been affected if some of the excluded records were actually infants of mothers residing within Detroit even if some neighborhoods were more likely than others to have missing census tracts.

Double counting births could have led to a high estimate of the demand for NICU beds if low-birthweight infants were more likely to have a duplicate record. This may have been the case because duplicates may have occurred when infants born in one hospital were transferred to another hospital and a birth certificate was completed at both the hospital of birth and the receiving hospital. Other duplicate entries may have occurred during the manual entry of records into the electronic database. The large number of duplicate records was a surprising finding, and if these hadn't been identified, could have biased the results. The Michigan Department of Community Health identified the problem of duplicate birth records in 1990 and took steps to eliminate this problem. However, investigators using birth certificate databases need to be alert to the potential of double counting births prior to 1990.

Accurately determining the demand for NICU beds requires accurate determination of birthweight and gestational-age because NICU admission and length of stay are closely related to birthweight. Errors in entering the birthweight or gestational-age on the birth certificates could bias the study results. The demand for NICU beds would artificially rise or fall if the birthweight or gestational-age entered on the birth certificate was consistently lower or higher than the actual birthweight or gestational-age. However, it is more likely that these data entry errors are equally distributed among preterm, term, low-birthweight, and normal birthweight infants. This non-systematic bias might obscure associations between independent and dependent variables but should not substantially affect the models created from the data.

Inaccurate determination of birthweight could lead to misclassification of infants among each of the categories: very low-birthweight, low birthweight, or normal birthweight. The association between birthweight and demand for NICU beds could be affected by these misclassification errors if these errors were differential (consistently either high or low). The risk of misclassification error is greatest among the smallest infants. It may be difficult to obtain an accurate birthweight in very low-birthweight infants because these infants often require resuscitation, respiratory support, tube feeding, and intravenous fluids. The effect of this would be minimal for those infants who were clearly less than

1,500 grams but might result in misclassification errors for those infants who were close to 1,500 grams. However, it seems unlikely that misclassification of infants just below the cut-off of 1,500 grams would be more or less likely than those just above the cut-off. It seems unlikely that these errors would introduce a systematic bias. Furthermore, it is likely that those infants just above 1,500 grams who require resuscitation would be just as likely to require NICU care as those defined as very low-birthweight.

The estimates of neighborhood demand for NICU beds could have been affected by inaccurately geocoded birth records. Data entry errors at MDCH or inaccurate entry of addresses at the hospital of birth could affect the distribution of birthweights among the neighborhoods. These errors would be expected to be non-differential (evenly distributed among neighborhoods) and would not be expected to bias the results. Likewise, data entry errors at the hospital of birth would probably be non-differential and would not bias the results.

ASSESSING THE POTENTIAL IMPACT OF LIMITATIONS OF THE STUDY

The limitations of this study do not meaningfully challenge the validity of the hypothesis: the population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. The discussion of the steps taken to assess the impact of the limitations of the study is divided into the following sections:

- Analysis of excluded records
- Comparison of study results with "known" demand in other populations

Analysis of Excluded Records

The mean birthweight, LBW rate, VLBW rate, IMR, NMR, and racial mix of the excluded records did not differ substantially from the study population. Therefore, it seems unlikely that a bias was introduced by exclusion of records with missing census tracts or assigning mean birthweight to those records missing birthweight data.

Comparison of Study Results with Other Studies

The comparisons made in this study evaluate the demand for NICU beds and not the number of beds required to meet this demand. The number of beds required to meet the demand in any given population would vary depending on allowance for variations in NICU size and number, inter-facility cooperation, tolerance for "no bed available days", and actual NICU utilization patterns. No attempt was made to compare these characteristics because the information provided in each study was insufficient to make such comparisons.

The fact that the actual demand experienced in Detroit (as reported in the MDCH Annual Hospital Statistical Survey) matched the demand predicted by the model supports the internal validity of the model. The external validity of the model is supported by the accuracy of the model in predicting the demand in the Northern Neonatal Network (NNN) in England.[69] Unfortunately, the study done by the Trent Regional Authority (TRA) in England did not present the actual utilization for both "high- and low-dependency" special care.[70] However, estimating the demand for "low-dependency" NICU care from the utilization pattern of the NNN, and applying this to the TRA data, revealed that the model was very accurate in predicting the demand for NICU beds. The study of demand in Utah estimated the demand for NICU beds rather than actual utilization. This may have "under-estimated" utilization. The Utah study also evaluated demand at a time when the national NMR was about 10%, but by 1987 had dropped to about 6.5%. This would make the demand less in 1977 because fewer infants were surviving to occupy NICU beds. Nevertheless, the model was relatively accurate in predicting the demand for NICU beds in Utah in 1977. Therefore, it is reasonable to assume that the NMR contributes very little to the variation in NICU demand when compared to the impact of birthweight.

SUMMARY

The linked databases used in this study appear to be an excellent resource for assessing community level risk factors for LBW. The strengths of the final database include the following characteristics: The variance in VLBW and neonatal mortality rates in the study population, the large number of births, the population-based nature of the data, and the large number of community level variables. The ability to identify the neighborhood of origin of each mother made it possible to assess the impact of high VLBW rates at the neighborhood level.

The results have demonstrated the wide variation in NICU bed demand among neighborhoods in Detroit and support the primary hypothesis of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. The secondary hypothesis of this thesis has also been supported: The demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population.

The method used to estimate NICU demand and cost may limit the validity of the model for predicting NICU demand in other populations. However, comparison of the model predicting demand with actual demand in Detroit and other populations suggests that the final model is accurate and may have potential value to health care planners and policy makers.

The preceding chapters have emphasized the importance of NICU care in the face of persistently high LBW rates in the United States, provided a conceptual framework for understanding the intimate relationship between LBW and NICU care, reviewed and critiqued the research regarding the demand for NICU beds, and presented the research methods and results of this study. The present chapter has been a discussion of the individual results of this study. The final chapter will discuss the implications of the present study for future research into factors affecting NICU resource utilization.

CHAPTER 7

CONCLUSIONS

The crucial role of NICU care in the face of persistently high LBW rates in the United States was introduced at the beginning of this thesis. The interaction between poverty and LBW was reviewed and the importance of NICU care was emphasized in Chapter 2. The lack of a valid model predicting the demand for NICU beds in a population was the focus of Chapter 3. The last three chapters have presented a study of NICU demand in Detroit, Michigan. The study confirms the primary and secondary hypotheses of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood and the demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population.

The conclusions of this thesis and implications of the study will be presented in the following sequence: methodological approach to studies of LBW, community level risk factors and LBW, the neighborhood as the unit of analysis in urban populations, and predicting the demand for NICU beds.

METHODOLOGIC APPROACH

This study demonstrates a methodological approach for future research into the causes and consequences of LBW. Combining geocoded birth certificates and death certificates with census tract data yields a powerful tool for research, assessment of health care services, and planning community health services. The methods used in this study could facilitate evaluation of community level risk factors while controlling for individual risk factors, neighborhood-level burden of LBW and PTB, and factors affecting demand for NICU resources in populations with varying risks. Adding hospital discharge data could strengthen this tool by facilitating outcome and cost analysis.

COMMUNITY LEVEL RISK FACTORS AND LOW-BIRTHWEIGHT

This study has revealed an association between measures of community-level poverty and LBW rates. Multiple community level measures of poverty are associated with LBW and VLBW among mothers residing within Detroit. There has been little prior research evaluating community-level "risk factors" while controlling for individual level risks. The present study suggests that community characteristics are associated with LBW and infant mortality but further research is needed. In a future study it would be helpful to evaluate the associations among community level markers of social class and VLBW, LBW, NMR, and IMR while controlling for confounding variables. These associations are likely to be complicated because of the complex interactions among gestational age, birthweight, community risk factors, and individual risk factors. The methods presented in the present study may provide a methodological foundation for future studies that attempt to address these complexities.

THE NEIGHBORHOOD: THE UNIT OF ANALYSIS IN URBAN POPULATIONS

Poverty, low-birthweight, neonatal intensive care, and infant mortality are closely and intricately inter-related. In Detroit, poverty contributes to the high LBW rate. The high LBW rate increases the IMR. The high LBW also increase the demand for NICU beds. However, poverty, LBW, infant mortality, and NICU bed demand in Detroit is not uniformly distributed. If the diversity of Detroit is representative of most urban populations, the primary hypothesis of this thesis has been substantiated: the population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. Detroit may be more economically diverse than most urban populations or the impact of poverty on LBW rates in Detroit may be more than most urban populations, although this seems unlikely. Duplicating this study in other urban populations would help test and refine this hypothesis.

In the face of a "shrinking health-care dollar", the ability to identify neighborhoods with the greatest demand for NICU beds could facilitate health-care planning. This is especially important given the benefit of NICU care in the face of persistently high LBW rates. The ability to assess community-level risk and the burden of individual risk at the neighborhood level would make it possible to determine the etiologic fraction of various risk factors for each neighborhood. This would enable public health officials to institute neighborhood-specific interventions to reduce LBW rates.

PREDICTING DEMAND FOR NICU BEDS

The LBW rate in general and the VLBW rate in particular must be closely related to the demand for NICU beds in a population. This study used a rational approach to assign infants to NICU admission status and to determine the length of stay. If this rational process closely approximates "reality" among LBW infants, the second hypothesis of this thesis has been proven: the demand for NICU beds in a population is closely related to the VLBW rate of the population. Duplicating this study in Detroit and other urban populations with hospital discharge data linked to the database would help test and refine this hypothesis. The model appears to be more accurate than existing estimates of NICU bed demand but should be further refined by utilizing a database that includes both NICU admission status and length of stay. This can now be accomplished because current birth certificates include NICU admission status, hospital discharge data records include NICU admission status and lengths of stay, and it is possible to link these databases.

The ability to predict demand for NICU care in a population given the VLBW rate can facilitate health-care planning. The inadequacy of current models for predicting the demand for NICU beds exists, in part, because these models have been based on homogenous populations, failed to adequately consider variation among populations with varying LBW risk factors or both. The model developed in this study makes it possible to predict the NICU bed demand given an intervention with a known impact on the VLBW rate. The cost and benefit of a proposed intervention can now be considered more realistically than was previously possible. Combined with the ability to identify neighborhood-level demand, this model can be a potent tool for health-care planning.

In the absence of measures to reduce the demand for NICU care, this study has demonstrated that the efficiency of NICU care can be improved by inter-facility cooperation. The theoretical model demonstrating the effect of varying levels of cooperation among NICUs in Detroit revealed a progressive increase in the number of beds needed to meet the demand as cooperation diminished. However, in an era of "managed competition" it may be difficult to realize this benefit of regionalization.

The importance of the model demonstrating the effect of NICU size and day-to-day variation in NICU demand cannot be overstated in a regulatory environment that fosters competition among health-care facilities. Competition among facilities, in effect, decreases the size of each NICU by increasing the number of beds needed to meet the demand for beds. It would be interesting to compare the efficiency of regionalized NICU care as measured by number of NICU beds required to meet the demand now and during the study period. In making such a comparison it would be important to remember the distinction between demand and utilization. Excess bed availability during periods of low NICU bed demand could lead to periodic over-utilization of NICU services and obscure differences in efficiency. This distinction between "true" demand (as determined by clinical criteria) and current utilization would best be evaluated in a NICU-based study. Such a study could be incorporated into a contemporary duplication and expansion of the population-based study presented in this thesis.

The demand for NICU beds was expressed in economic terms in this study in order to demonstrate the differential burden of LBW among neighborhoods in Detroit. The neighborhood-specific incremental cost varied by more than four-fold among neighborhoods within Detroit as modeled by the crude estimates of NICU cost. Evaluating the burden of LBW in an urban population using this or a similar model could facilitate cost-effective interventions by identifying neighborhoods experiencing a disproportionate burden from LBW. The model could be improved by incorporating actual birthweight-specific NICU cost based on hospital discharge data. Still, the estimation procedure has demonstrated the disproportionate financial burden in neighborhoods with high VLBW rates.

SUMMARY

The results of this study support the primary hypothesis of this thesis: The population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood. The secondary hypothesis of this thesis is also supported: The demand for NICU beds in a population is closely related to the very low-birthweight (VLBW) rate of the population. However, as noted, the model predicting NICU demand could have been strengthened if the actual NICU admission status, length of stay, and cost were available.

Furthermore, advances in neonatal intensive care may limit the contemporary validity of the model. For example, subsequent to 1988, the treatment of lung disease associated with PTB has improved survival among LBW infants. This may affect the length of NICU stay by shortening the stay of larger LBW infants and increasing the survival (and LOS) of smaller VLBW infants.[51] Nevertheless, compared to current recommendations, the NICU bed demand model presented in this thesis would seem to be more sensitive to variations across populations.

Several factors make this an ideal time to repeat and expand this study in the City of Detroit. Geocoding has become easier and more efficient over the past 20 years, since 1989 birth certificates have identified NICU admission status and contain more individual level risk data, hospital discharge data is more complete and of better quality, and competition among health-care facilities has increased over the past ten years. A new study could compare NICU utilization "then and now".

The following improvements should be made:

- Link birth certificate, death certificate, census tract data, and hospital discharge data
- Model the effect of birthweight on incremental NICU cost using "local" data
- Assess ecological variables for confounding by including individual-level variables now available on birth certificates and incorporating a NICU based component to capture additional individual-level characteristics
- Determine attributable risk for individual and community level risk factors by neighborhood

In the mean time, it seems clear that the population of interest in determining NICU resource utilization in large metropolitan areas is the neighborhood and that the demand for NICU beds in a population is closely related to the very low-birthweight rate of the population.

GLOSSARY

Case-mix: The combination of mildly, moderately, and severely ill patients in a hospital

Cost shifting: Inflating charges to private insurers to cover uncompensated care render to indigent and "under-insured" patients

Cross-subsidization: Inflating charges for lab and other ancillary services to cover uncompensated care render to indigent and "under-insured" patients

Diagnosis related group: A group of diagnoses that are clinically similar

Direct costs: hospital and physician charges for care of sick newborns in neonatal intensive care units and the cost of caring for subsequent handicaps in survivors

Ecological variable: A characteristic of a group being studied: For example, median household income. This is in contrast to an individual characteristic: For example, the household income of the 7th record in a database.

Extremely low-birthweight: Birthweight less than 1000 grams

Gestational age: The age of a fetus expressed in days or weeks

Indirect costs: Travel expenses, income lost as a result of missing work, and similar expenses incurred as a result of illness

Infant mortality rate: The number of deaths in infants one year of age or less divided by the number of live births during the same time period

Intangible cost: Emotional stress, social stress, and similar non-economic losses as a result of illness

Intrauterine Growth Retardation: An infant whose birthweight is below the tenth percentile for its gestational age

Live birth: A newborn that breathes or shows any sign of life at birth.

Low-birthweight: Birthweight less than 2500 grams

Neonatal mortality rate: The number of deaths in infants 27 days of age or less divided by the number of live births during the same time period

Nulliparity: The status of a woman who has not had any births

Neonate: A newborn child, especially less than 28 days old

Parity: The number of births a woman has had

Preterm birth: Birth before 37 weeks of gestation have been completed

Selection bias: A systematic difference between the characteristics of individuals selected for inclusion in a study and those who are not.

Very low-birthweight: Birthweight less than 1500 grams

World Health Organization: An agency of the United Nations whose aim is to attain the highest level of health for all people of the world

Years of Potential Life Lost: The sum of the years that a group of people would have lived if they had not died from a given disease or injury before having reached their normal life expectancy

APPENDICES

APPENDIX A

Classification of Perinatal Centers

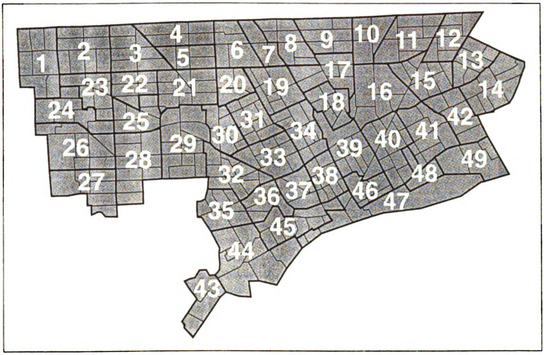
Basic Perinatal Centers (Level-I) provide: basic inpatient care for pregnant women and newborns without complications; management of perinatal emergencies, including neonatal resuscitation; leadership in early risk identification before and at birth; consultation or referral for high-risk patients; and public and professional education. Such centers should have physician, nursing and allied health staff to support these functions. Physical facilities should include clinical laboratory, x-ray and ultrasound services available on a 24-hour basis.

Specialty Perinatal Centers (Level-II) provide: management for certain high-risk pregnancies, including maternal referrals from basic care centers; services for newborns with selected complications, particularly those who are moderately ill; and appropriate continuing education. The staff of specialty perinatal care centers should include an appropriate array of physician, nursing and allied health staff to support these functions, including but not limited to one or more of each of the following: pediatricians, obstetricians, family physicians, anesthesiologists, nurses with advanced training and certification in perinatal care, respiratory therapists and laboratory technicians.

Subspecialty Perinatal Centers (Level-III) provide: inpatient care for maternal and fetal complications; a NCIU equipped to treat critically ill neonates; follow-up medical care of NICU graduates; consultation and referral arrangements with other hospitals (including transport arrangements); educational opportunities; a perinatal database; and evaluation activities. These centers should have physician, nursing and allied health staff available to support these functions, including but not limited to one or more of each of the following: obstetricians with recognized expertise in high-risk pregnancy management, neonatologists, obstetric anesthesiologists, perinatal social workers, continuing education staff, genetics counselors, appropriate types of certified advanced-pediatric nurses, pathologists and pediatric subspecialists.

APPENDIX B

Neighborhoods within the City of Detroit



1	Redford	18	Hamtramck*	35	Chadsey
2	Evergreen	19	Highland Park*	36	Condon
3	Greenfield	20	McNichols	37	Jefferies
4	Pembroke	21	Harmony village	38	University
5	Bagley	22	Cerveny	39	Chene
6	Palmer Park	23	Rosedale Park	40	Kettering-Butzel
7	State Fair	24	Brightmoor	41	St. Jean
8	Nolan	25	Grandmont	42	Mack
9	Pershing	26	Cody	43	Boynton
10	Grant	27	Rouge	44	Delray-Springwells
11	Mt. Olivet	28	Brooks	45	Clark Park
12	Burbank	29	Mackenzie	46	Lafayette
13	Denby	30	Winterhalter	47	Central Business District
14	Finney	31	Durfee	48	Indian Village
15	Connor	32	Tireman	49	East-Riverside
16	Airport	33	Rosa Parks		
17	Davison	34	Central		

* Hamtramck & Highland Park are separate administrative units within Detroit and are not included in the study

APPENDIX C

List of **all** fields in the Michigan Inpatient Database

#	Field	#	Field
1	Hospital ID #	31	Attending physician
2	Discharge key	32	Disposition
3	Medical record #	33	Autopsy
4	Sex	34	Operative death
5	Race	35	Coroners case
6	Birth date	36	Admit diagnosis
7	Age code	37	Principle diagnosis
8	Age in years	38	Diagnostic count
9	Age in months	39	Major diagnostic category
10	Age in days	40	Diagnostic related group
11	Zip code	41	CPHA List A
12	Admit date	42	Diagnostic category
13	Admit hour	43	Principal procedure
14	Admit weekday	44	Principal procedure LOS
15	Discharge date	45	Surgeon
16	Discharge year	46	Pathologic tissue diagnosis
17	Discharge month	47	First surgery day
18	Length of Stay (LOS)	48	First surgery time
19	Admit condition	49	CPHA List B
20	Admit from	50	Episode count
21	ER admission	51	Total charges
22	Readmission	52	Principal payor
23	CPHA Service	53	Resource need unit
24	Hospital service	54	Age category
25	ICU used	55	Pediatric age category
26	ICU days	56	Geriatric age category
27	CCU used		
28	CCU days		
29	SCU used		
30	SCU days		

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APPENDIX C (continued)

List of fields in MIDB database **requested** for this study including description of fields

#	Field	Description
2	Discharge key	CPHA - assigned patient discharge key.
4	Sex	Sex of patient
5	Race	As defined by patient
6	Birth date	Birth date of patient (YYMMDD format)
11	Zip code	Zip code of residence of patient
12	Admit date	Admission date (YYMMDD format)
13	Admit hour	Utilizes military time
15	Discharge date	Date of death, discharge, or transfer
18	Length of stay	Length of hospital stay in days
20	Admit from	Source of admission e.g. acute care facility
23	CPHA service	Service patient admitted to e.g. pediatrics
24	Hospital service	Hospital defined admission service
25	ICU used	1 = yes 0 = no
26	ICU days	LOS in ICU in days
29	SCU used	1 = yes 0 = no
30	SCU days	LOS in SCU in days
32	Disposition	Event ending patient stay e.g. died
36	Admit diagnosis	ICD-9 diagnostic code on admission
37	Principal diagnosis	Final ICD-9 diagnostic code at discharge
38	Diagnostic count	Total number of recorded diagnoses
39	Major diagnostic category	HCFA's designated category
40	Diagnosis-related group (DRG)	HCFA's designated DRG
42	Diagnostic category	Diagnosis/operation status indicators
43	Principal procedure	Principal ICD-9 procedure code
52	Principal payor	Expected principal source of payment
53	Resource need unit	Relative resource utilization

APPENDIX D

List of all fields in matched birth and death records database

#	Field	#	Field
1	Year of death	31	Death occurrence state
2	Death certificate number	32	Death occurrence county
3	Year of birth	33	Death occurrence MCD
4	Birth certificate number	34	NCHS place of injury
5	Month of death	35	Michigan place of injury
6	Day of death	36	Sex at death
7	Month of birth	37	Race at birth
8	Day of birth	38	Race at death
9	Last menses year	39	Age unit at death
10	Last menses month	40	Age at death
11	Last menses day	41	Age group
12	Last live birth year	42	Autopsy
13	Last live birth month	43	Underlying cause prefix
14	Last live birth day	44	Underlying cause of death
15	Last fetal death year	45	Code of underlying cause of death
16	Last fetal death month	46	Related cause of death 1 line #
17	Last fetal death day	47	Related cause of death 2 line #
18	Birth residence state	48	Related cause of death 3 line #
19	Birth residence county	49	Related cause of death 4 line #
20	Birth residence MCD	50	Related cause of death 5 line #
21	Birth residence census tract	51	Related cause of death 6 line #
22	Detroit census area	52	Related cause of death 7 line #
23	Death residence state	53	Related cause of death 8 line #
24	Death residence county	54	Related cause of death 9 line #
25	Death residence MCD	55	Related cause of death 10 line #
26	Death residence census tract	56	Related cause of death 11 line #
27	Detroit census area	57	Related cause of death 12 line #
28	Birth occurrence state	58	Related cause of death 13 line #
29	Birth occurrence county	59	Related cause of death 1 code #
30	Birth occurrence MCD	60	Related cause of death 2 code #

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APPENDIX D (continued)

List of all fields in matched birth and death records database

#	Field	#	Field
61	Related cause of death 3 code #	91	Education of mother
62	Related cause of death 4 code #	92	Age of father
63	Related cause of death 5 code #	93	Race of father
64	Related cause of death 6 code #	94	Education of father
65	Related cause of death 7 code #	95	Previous children born - now living
66	Related cause of death 8 code #	96	Previous children born - now dead
67	Related cause of death 9 code #	97	Previous children born dead
68	Related cause of death 10 code #	98	Month prenatal care began
69	Related cause of death 11 code #	99	Number of prenatal visits
70	Related cause of death 12 code #	100	Calculated weeks of gestation
71	Related cause of death 13 code #	101	Mother's zip code
72	Plurality	102	Multiple birth order
73	Sex at birth	103	Estimated weeks of gestation
74	Birthweight pounds	104	Terminations before 20 weeks
75	Birthweight ounces	105	Terminations after 20 weeks
76	Birthweight grams	106	Terminations unknown weeks
77	Weight indicator	107	1 minute apgar
78	Complications related to pregnancy	108	5 minute apgar
79	Concurrent illnesses or condition	109	Complication of pregnancy 1
80	Labor and/or delivery complication	110	Complication of pregnancy 2
81	Birth injury	111	Complication of pregnancy 3
82	Congenital malformation 1	112	Complication of pregnancy 4
83	Congenital malformation 2	113	Complication of pregnancy 5
84	Congenital malformation 3	114	Patient status – hospital deaths
85	Congenital malformation 4	115	Medical examiner referral
86	Eyes treated	116	Actual place of death
87	Blood test	117	Medical examiner certification
88	Attendant at birth	118	State of birth – death certificate
89	Age of mother		
90	Race of mother		

APPENDIX E

Birthweight distribution by neighborhood - Detroit, Michigan (1984 -1988)
(In order of increasing median birthweight)

		Distribution			
Code	**Geographic Unit**	**Low**	**High**	**Mean**	**Median**
34	Central	520	4990	2986	3062
33	Rosa Parks	510	5160	3038	3090
39	Chene	520	4961	3047	3090
42	Mack	500	5443	3049	3110
41	St. Jean	510	5160	3050	3116
16	Airport	500	5799	3065	3119
40	Kettering-Butzel	510	5301	3048	3119
49	East-Riverside	575	4990	3087	3119
32	Tireman	500	7165	3069	3120
29	Mackenzie	539	5613	3091	3140
8	Nolan	500	5216	3098	3147
20	McNichols	515	5336	3051	3147
21	Harmony Village	500	5685	3094	3147
30	Winterhalter	500	5941	3066	3147
31	Durfee	500	5216	3077	3147
36	Condon	510	5613	3075	3147
3	Greenfield	500	5330	3131	3175
4	Pembroke	516	6010	3133	3175
9	Pershing	510	4990	3127	3175
15	Connor	505	5188	3112	3175
25	Grandmont	567	5664	3146	3175
37	Jeffries	560	5260	3080	3175
38	University	550	5273	3123	3175

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APPENDIX E (continued)

Birthweight distribution by neighborhood - Detroit, Michigan (1984 -1988)
(In order of increasing median birthweight)

		Distribution			
Code	**Geographic Unit**	**Low**	**High**	**Mean**	**Median**
43	Boynton	510	4820	3114	3175
46	Lafayette	620	5698	3132	3186
22	Cerveny	510	5301	3154	3190
48	Indian Village	652	4706	3126	3195
5	Bagley	649	5460	3155	3204
17	Davison	520	6162	3156	3204
26	Cody	540	5557	3171	3204
24	Brightmoor	510	5698	3167	3220
28	Brooks	500	5273	3157	3220
47	Central Business District	600	4536	3144	3225
2	Evergreen	520	5500	3174	3232
10	Grant	850	5046	3204	3232
7	State Fair	510	5429	3193	3250
6	Palmer Park	580	5035	3215	3269
12	Burbank	500	5940	3216	3270
11	Mt. Olivet	500	5216	3221	3280
44	Delray-Springwells	595	6067	3233	3280
23	Rosedale Park	624	6123	3243	3289
45	Clark Park	537	6180	3253	3289
14	Finney	510	5120	3275	3317
35	Chadsey	540	5528	3271	3317
13	Denby	500	5103	3301	3345
27	Rouge	595	5160	3303	3345
1	Redford	520	5330	3336	3400

APPENDIX F

Selected demographic characteristics by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of blacks)

		Demographic Characteristic			
Code	**Geographic Unit**	**% Black**	**% ≤ 15 years old**	**% ≥ 65 years old**	**Median Age of Mothers**
44	Delray-Springwells	10.34	27.23	10.75	23
35	Chadsey	13.88	26.85	13.42	24
45	Clark Park	14.65	25.87	10.45	23
1	Redford	42.22	22.35	10.71	26
14	Finney	45.63	24.90	12.59	26
12	Burbank	48.32	30.65	10.48	25
13	Denby	48.66	25.24	11.15	27
11	Mt. Olivet	51.40	27.04	11.25	25
7	State Fair	51.76	31.31	8.25	25
48	Indian Village	57.04	8.38	31.39	27
17	Davison	62.30	28.18	14.10	24
38	University	65.01	8.78	21.81	25
24	Brightmoor	65.43	32.89	6.03	24
36	Condon	65.58	23.84	17.36	23
47	Central Business District	66.83	3.18	12.52	27
26	Cody	70.15	28.00	7.87	25
27	Rouge	70.15	22.21	15.97	26
37	Jeffries	75.17	19.81	19.86	24
28	Brooks	75.36	27.8	9.06	24
10	Grant	76.03	29.65	8.82	25
23	Rosedale Park	77.96	25.81	25.81	29
6	Palmer Park	80.26	16.95	7.75	28
0	City of Detroit	75.55	24.66	12.23	24.00

(Source: 1990 US Census)

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APPENDIX F (continued)

Selected demographic characteristics by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of blacks)

		Demographic Characteristic			
Code	**Geographic Unit**	**% Black**	**% < 15 years old**	**% ≥ 65 years old**	**Median Age of Mothers**
46	Lafayette	81.86	13.03	23.14	27
49	East-Riverside	83.85	27.99	9.04	23
9	Pershing	84.81	23.13	15.50	25
15	Connor	86.71	33.1	5.39	24
43	Boynton	86.95	23.28	19.62	24
2	Evergreen	87.19	27.12	7.90	26
39	Chene	87.83	24.71	15.69	23
16	Airport	87.90	30.60	9.17	22
8	Nolan	89.76	25.50	13.14	23
3	Greenfield	93.57	24.55	9.27	25
42	Mack	93.67	30.39	7.05	23
34	Central	93.91	18.69	18.93	23
40	Kettering-Butzel	94.11	21.00	20.37	23
25	Grandmont	95.06	27.79	5.05	24
22	Cerveny	95.18	24.41	6.78	24
33	Rosa Parks	96.18	22.33	18.67	23
41	St. Jean	96.55	23.62	14.44	22
29	Mackenzie	96.56	25.05	10.17	23
4	Pembroke	97.70	17.82	15.26	25
20	McNichols	97.81	22.71	15.39	24
21	Harmony Village	97.93	23.95	9.60	23
5	Bagley	98.00	18.04	13.72	25
31	Durfee	98.32	22.27	17.43	23
30	Winterhalter	98.77	23.41	14.54	23
32	Tireman	98.96	23.97	15.93	23
0	City of Detroit	75.55	24.66	12.23	24.00

(Source: 1990 US Census)

APPENDIX G

Selected economic characteristics by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of female head of household)

		Economic Characteristic*					
Code	**Geographic Unit**	**% CAR**	**MHI**	**%APL**	**%<HS**	**%FHH**	**MYME**
47	Central Business District	0.86	20,815	51.03	78.87	6.27	12
48	Indian Village	16.72	24,372	74.37	84.18	8.76	13
38	University	2.12	8,438	34.15	80.22	10.48	12
6	Palmer Park	15.70	46,111	88.92	86.10	14.03	14
27	Rouge	39.77	26,907	77.38	64.54	17.44	12
1	Redford	24.78	27,614	75.36	67.00	17.56	12
46	Lafayette	13.07	20,371	65.36	83.04	17.98	13
13	Denby	39.26	29,076	76.82	68.47	21.37	12
23	Rosedale Park	33.24	45,295	87.55	78.97	22.06	14
14	Finney	34.68	28,340	71.82	71.71	22.85	12
45	Clark Park	22.70	13,793	44.73	74.21	23.69	11
34	Central	22.59	11,835	46.25	74.62	25.38	12
11	Mt. Olivet	39.67	23,273	64.12	65.18	25.55	12
37	Jeffries	14.49	9,094	34.85	74.05	26.38	12
44	Delray-Springwells	28.72	13,776	50.08	72.91	26.43	11
35	Chadsey	35.24	16,115	51.5	70.07	27.09	11
4	Pembroke	35.88	30,636	75.71	74.86	27.45	12
26	Cody	28.18	25,405	67.65	65.24	28.17	12
5	Bagley	38.51	35,060	80.48	73.66	28.38	12
43	Boynton	40.74	18,148	62.05	70.34	28.67	12
12	Burbank	33.87	21,879	58.74	66.24	30.42	12
7	State Fair	23.31	10,620	35.93	77.25	30.45	11
0	City of Detroit	30.12	17,348	56.86	71.49	30.28	12

***Economic variables: %car** = Percent homes with at least one car, **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%<HS** = Percent of adult population without high school education, **%FHH** = Percent female head of household, **MYME** = Median years of maternal education (Source: MYME from birth certificates, all others 1990 US Census)

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APPENDIX G (continued)

Selected economic characteristics by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of female head of household)

		Economic Characteristic*					
Code	**Geographic Unit**	**% car**	**MHI**	**%APL**	**%<HS**	**%FHH**	**MYME**
9	Pershing	44.36	24,536	66.06	67.63	31.01	12
3	Greenfield	34.84	27,737	69.02	69.58	32.68	12
36	Condon	32.39	11,766	43.39	74.24	32.72	11
22	Cerveny	34.27	29,523	71.58	72.61	33.35	12
2	Evergreen	32.08	29,364	69.59	70.16	33.42	12
33	Rosa Parks	23.84	11,804	43.55	74.35	33.42	12
31	Durfee	25.98	13,630	50.39	72.93	33.64	12
30	Winterhalter	24.08	13,602	48.92	72.24	33.73	12
17	Davison	42.04	14,993	46.23	70.67	34.53	12
28	Brooks	32.41	20,836	55.62	67.35	34.80	12
40	Kettering-Butzel	32.34	12,174	42.17	74.17	34.93	12
20	McNichols	35.39	16,531	54.18	75.92	35.49	12
10	Grant	35.47	22,103	59.8	68.76	35.72	12
8	Nolan	37.73	17,348	54.17	69.00	36.33	12
41	St. Jean	30.58	10,906	38.90	72.15	36.79	12
24	Brightmoor	25.69	16,678	47.21	68.44	37.07	12
32	Tireman	31.62	11,688	43.35	70.90	37.61	12
29	Mackenzie	31.94	19,271	56.85	69.71	37.71	12
25	Grandmont	30.91	25,567	61.92	69.55	37.94	12
49	East-Riverside	30.58	15,766	46.11	76.17	38.50	12
39	Chene	26.70	10,141	32.28	76.11	38.69	12
21	Harmony Village	36.35	19,968	56.98	69.65	39.19	12
16	Airport	35.36	11,855	40.79	71.84	41.29	12
15	Connor	28.26	16,873	48.83	70.47	41.50	12
42	Mack	21.77	9,885	34.79	74.08	42.12	11
0	City of Detroit	30.12	17,348	56.86	71.49	30.28	12

***Economic variables: %car** = Percent homes with at least one car, **MHI** = Median household income ($1990), **%APL** = Percent of households with family income above 150% of federal poverty level, **%<HS** = Percent of adult population without high school education, **%FHH** = Percent female head of household, **MYME** = Median years of maternal education (Source: MYME from birth certificates, all others 1990 US Census)

APPENDIX H

Selected environmental characteristics by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of vacant housing)

		Environmental Characteristic*				
Code	**Geographic Unit**	**%VH**	**%RO**	**MPV**	**%CR**	**%<1940**
4	Pembroke	2.92	23.48	34364	3.74	10.77
5	Bagley	3.10	22.27	38253	2.94	28.95
27	Rouge	3.43	22.62	26178	3.54	39.77
9	Pershing	3.72	25.42	23663	5.61	14.43
23	Rosedale Park	3.75	13.54	47217	2.37	33.24
22	Cerveny	3.92	30.00	31166	5.27	34.27
3	Greenfield	4.24	29.97	31265	5.54	9.64
2	Evergreen	4.48	30.93	30853	6.32	12.77
13	Denby	4.55	24.78	28821	4.11	17.52
1	Redford	4.90	40.77	32084	3.32	10.65
14	Finney	4.97	29.66	33104	3.09	35.69
43	Boynton	5.01	27.10	25410	5.08	40.74
10	Grant	5.38	34.19	22803	6.71	17.42
11	Mt. Olivet	5.50	29.38	25497	5.62	14.58
26	Cody	5.68	41.28	27565	5.80	28.18
12	Burbank	5.75	34.14	26293	5.95	20.40
8	Nolan	5.88	34.46	19968	6.82	33.82
6	Palmer Park	5.94	41.20	87049	1.42	53.43
25	Grandmont	6.14	36.92	30172	5.95	30.91
29	Mackenzie	6.20	40.34	24827	6.44	31.94
21	Harmony Village	6.85	37.37	23958	5.86	36.35
15	Connor	7.16	46.93	23977	8.82	26.90
17	Davison	7.28	40.81	15799	7.02	52.04
24	Brightmoor	7.89	54.02	19139	8.34	25.69
0	City of Detroit	8.77	42.96	25,600	4.96	35.79

***Environmental Characteristics: %VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value, **%CR** = Percent crowding, **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

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APPENDIX H (continued)

Selected environmental characteristic by neighborhood - Detroit, Michigan (1990)
(In order of increasing percent of vacant housing)

		Environmental Characteristic*				
Code	**Geographic Unit**	**%VH**	**%RO**	**MPV**	**%CR**	**%<1940**
46	Lafayette	8.41	71.91	71843	2.28	13.07
48	Indian Village	8.42	63.15	92860	1.51	16.72
20	McNichols	8.63	40.03	21634	4.11	35.39
16	Airport	8.95	44.00	17251	7.90	40.44
40	Kettering-Butzel	9.30	51.31	16160	4.66	32.34
44	Delray-Springwells	9.30	50.24	15021	5.22	28.72
32	Tireman	9.84	45.52	17190	4.66	31.62
30	Winterhalter	10.06	54.74	25082	4.76	24.08
41	St. Jean	10.20	51.88	15701	5.91	30.58
31	Durfee	10.30	54.81	26705	4.06	25.98
28	Brooks	10.49	39.80	23581	7.22	32.41
35	Chadsey	10.60	39.61	15171	5.11	35.24
33	Rosa Parks	10.71	59.88	20585	4.68	23.84
7	State Fair	11.48	57.09	16994	14.39	46.30
36	Condon	11.57	47.18	14999	5.85	32.39
39	Chene	11.94	56.53	14983	7.11	26.70
45	Clark Park	12.64	52.87	15997	8.23	22.70
34	Central	14.37	58.69	25123	3.95	22.59
49	East-Riverside	14.65	44.24	25288	5.47	30.58
42	Mack	16.78	54.53	18353	8.30	21.77
38	University	22.90	75.20	41169	6.80	2.12
37	Jeffries	28.76	56.72	20420	3.62	14.49
47	Central Business District	29.71	68.82	132244	3.82	0.86
0	City of Detroit	8.77	42.96	25,600	4.96	35.79

***Environmental Characteristics: %VH** = Percent vacant housing, **%RO** = Percent renter occupied, **MPV** = Median property value, **%CR** = Percent crowding, **%<1940** = Percent housing constructed before 1940 (Source: 1990 US Census)

APPENDIX I

Low-birthweight Rate (LBWR) per 100 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) by Demographic Variable - Detroit, Michigan (1984 –1988)

Variable	Number of Births < 2500 gm	Number of Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Race of Infant				
White (1)	1502	19700	7.6	Reference
Other Asian or Pacific Islander (0)	30	537	5.6	0.7 (0.5, 1.1)
Black (2)	9255	64544	14.3	1.9 (1.8, 2.0)
American Indian (3)	20	205	9.8	1.3 (0.8, 2.0)
Chinese (4)	2	72	2.8	0.4 (0.1, 1.5)
Japanese (5)	4	17	23.5	3.1 (1.0, 9.2)
Filipino (6)	8	122	6.6	0.9 (0.4, 1.8)
Hawaiian (7)	-	23	-	-
Other Non-white (8)	2	24	8.3	1.1 (0.3, 4.6)
Unknown (9)	5	45	11.1	1.5 (0.6, 3.7)
Maternal age				
17 – 34	9517	75765	12.6	Reference
≤ 16	575	4456	12.9	1.0 (0.9, 1.1)
≥ 35	736	5049	14.6	1.2 (1.1, 1.3)
Gender of Infant				
Female	5780	41736	13.9	Reference
Male	5046	43529	11.6	0.8 (0.8, 0.9)
Unknown	2	5	40.0	2.9 (0.6, 14.9)
Percent of population black				
≤ 65.01	2228	22053	10.1	Reference
> 65.01 to ≤ 86.95	2571	21215	12.1	1.2 (1.1, 1.3)
> 86.95 to ≤ 95.18	3011	20930	14.4	1.4 (1.3, 1.5)
> 95.18	3018	21072	14.3	1.4 (1.3, 1.5)
Percent of population ≤ 15 years old				
≤ 23.28	2871	21324	13.5	Reference
> 23.28 to ≤ 25.05	3027	22141	13.7	1.0 (1.0, 1.0)
> 25.05 to ≤ 27.80	2340	21490	10.9	0.8 (0.8, 0.9)
> 27.80	2590	20315	12.8	1.0 (0.9, 1.0)
Percent of population ≥ 65 years old				
≤ 9.06	2920	20053	14.6	Reference
> 9.06 to ≤ 10.75	2312	19360	11.9	0.8 (0.8, 0.9)
> 10.75 to ≤ 15.50	2667	22413	11.9	0.8 (0.8, 0.9)
> 15.50	2929	20090	14.6	1.0 (1.0, 1.1)

*(Source: 1990 US Census)

APPENDIX J

Very Low-birthweight Rate (VLBWR) per 100 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) by Demographic Variable - Detroit, Michigan (1984 – 1988)

Variable	Number of Births < 1500 gm	Number of Live Births	% VLBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Race of Infant (Field 37)				
White (1)	228	19700	1.2	Reference
Other Asian or Pacific Islander (0)	3	537	0.6	0.5 (0.2, 1.5)
Black (2)	1906	64544	3.0	2.6 (2.2, 2.9)
American Indian (3)	4	205	2.0	1.7 (0.6, 4.6)
Chinese (4)	-	72	-	-
Japanese (5)	1	17		5.1 (0.7, 38.4)
Filipino (6)	-	122	-	-
Hawaiian (7)	-	23	-	-
Other Non-white (8)	-	24	-	-
Unknown (9)	-	45	-	-
Maternal age				
17 – 34	1881	75765	2.5	Reference
≤ 16	120	4456	2.7	1.1 (0.9, 1.3)
≥ 35	141	5049	2.8	1.1 (1.0, 1.3)
Gender of Infant				
Female	1058	41736	2.5	Reference
Male	1082	43529	2.5	1.0 (0.90, 1.1)
Unknown	2	5	40.0	15.8 (3.1, 81.4)
Percent of population black*				
≤ 65.01	398	22053	1.8	Reference
> 65.01 to ≤ 86.95	500	21215	2.4	1.3 (1.1, 1.5)
> 86.95 to ≤ 95.18	620	20930	3.0	1.6 (1.5, 1.9)
> 95.18	624	21072	3.0	1.6 (1.4, 1.9)
Percent of population ≤ 15 years old*				
≤ 23.28	602	21324	2.8	Reference
> 23.28 to ≤ 25.05	594	22141	2.7	1.0 (0.9, 1.1)
> 25.05 to ≤ 27.80	448	21490	2.1	0.7 (0.7, 0.8)
> 27.80	498	20315	2.5	0.9 (0.8, 1.0)
Percent of population ≥ 65 years old*				
≤ 9.06	558	20053	2.8	Reference
> 9.06 to ≤ 10.75	454	19360	2.4	0.8 (0.7, 1.0)
> 10.75 to ≤ 15.50	533	22413	2.4	0.9 (0.8, 1.0)
> 15.50	597	20090	3.0	1.1 (1.0, 1.2)

*(Source: 1990 US Census)

APPENDIX K

Low-birthweight Rate (LBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for all economic variables - Detroit, Michigan (1984 –1988)

Variable	Number of Births < 2500 gm	Number of Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Homes with at least one car (%)*				
≥ 35.36	2699	22162	12.2	Reference
< 35.36 to ≥ 32.08	2688	22702	11.8	1.0 (0.9, 1.0)
< 32.08 to ≥ 26.70	2622	19710	13.3	1.1 (1.0, 1.2)
< 26.70	2819	20696	13.6	1.1 (1.1, 1.2)
Median household income ($1990)*				
≥ 25405	2367	22330	10.7	Reference
< 25405 to ≥ 17348	2641	21164	12.5	1.2 (1.1, 1.2)
< 17348 to ≥ 12174	2866	22728	12.6	1.2 (1.1, 1.3)
< 12174	2954	19048	15.5	1.5 (1.4, 1.5)
Households with family income above 150% of federal poverty level (%)*				
≥ 66.06	2446	22849	10.7	Reference
< 66.06 to ≥ 54.17	2708	21607	12.5	1.2 (1.1, 1.2)
< 54.17 to ≥ 44.73	2655	20918	12.7	1.2 (1.1, 1.3)
< 44.73	3019	19896	15.2	1.4 (1.3, 1.5)
Percent female head of household*				
≤ 27.09	2366	22377	10.57	Reference
> 27.09 to ≤ 33.42	2687	21592	12.44	1.2 (1.1, 1.3)
> 33.42 to ≤ 37.07	2803	20417	13.73	1.3 (1.2, 1.4)
> 37.07	2972	20884	14.23	1.4 (1.3, 1.4)
Maternal education				
> 12 years	2366	22069	10.7	Reference
12 years	3990	32915	12.1	1.1 (1.1, 1.2)
< 12 years	4361	29787	14.6	1.4 (1.3, 1.4)
Percent of adult population without high school education*				
≤ 69.00	2463	22290	11.1	Reference
> 69.00 to ≤ 70.67	2648	21185	12.5	1.1 (1.1, 1.2)
> 70.67 to ≤ 74.08	2922	21805	13.4	1.2 (1.2, 1.3)
> 74.08	2795	19990	14.0	1.3 (1.2, 1.3)

*(Source: 1990 US Census)

APPENDIX L

Very Low-birthweight Rate (VLBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for all economic variables - Detroit, Michigan (1984 –1988)

Variable	Number of Births < 1500 gm	Number of Live Births	% VLBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Homes with at least one car (%)*				
≥ 35.36	546	22162	2.5	Reference
< 35.36 to ≥ 32.08	558	22702	2.5	1.0 (0.9, 1.1)
< 32.08 to ≥ 26.70	490	19710	2.5	1.0 (0.9, 1.1)
< 26.70	548	20696	2.7	1.1 (1.0, 1.2)
Median household income ($1990)*				
≥ 25405	481	22330	2.2	Reference
< 25405 to ≥ 17348	529	21164	2.5	1.2 (1.0, 1.3)
< 17348 to ≥ 12174	541	22728	2.4	1.1 (1.0, 1.3)
< 12174	591	19048	3.1	1.4 (1.3, 1.6)
Households with family income above 150% of federal poverty level (%)*				
≥ 66.06	497	22849	2.2	Reference
< 66.06 to ≥ 54.17	557	21607	2.6	1.2 (1.1, 1.3)
< 54.17 to ≥ 44.73	485	20918	2.3	1.1 (1.0, 1.2)
< 44.73	603	19896	3.0	1.4 (1.2, 1.6)
Percent female head of household*				
≤ 27.09	429	22377	1.9	Reference
> 27.09 to ≤ 33.42	576	21592	2.7	1.4 (1.2, 1.6)
> 33.42 to ≤ 37.07	555	20417	2.7	1.4 (1.3, 1.6)
> 37.07	582	20884	2.8	1.5 (1.3, 1.7)
Maternal education				
> 12 years	526	22069	2.4	Reference
12 years	814	32915	2.5	1.0 (0.9, 1.2)
< 12 years	802	29787	2.7	1.1 (1.0, 1.3)
Percent of adult population without high school education*				
≤ 69.00	489	22290	2.2	Reference
> 69.00 to ≤ 70.67	520	21185	2.5	1.1 (1.0, 1.3)
> 70.67 to ≤ 74.08	572	21805	2.6	1.2 (1.1, 1.4)
> 74.08	561	19990	2.8	1.3 (1.1, 1.5)

*(Source: 1990 US Census)

APPENDIX M

Low-birthweight Rate (LBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for all environmental variables - Detroit, Michigan (1984 –1988)

Variable*	Number of Births < 2500 gm	Number of Live Births	% LBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Percent vacant housing				
≤ 5.50	2526	23814	10.6	Reference
> 5.50 to ≤ 7.16	2434	19151	12.7	1.2 (1.1, 1.3)
> 7.16 to ≤ 10.30	2992	21649	13.8	1.3 (1.2, 1.4)
> 10.30	2876	20656	13.9	1.3 (1.2, 1.4)
Percent renter occupancy				
≤ 30.93	2331	21598	10.8	Reference
> 30.93 to ≤ 40.77	2627	21503	12.2	1.1 (1.1, 1.2)
> 40.77 to ≤ 51.88	2970	21971	13.5	1.3 (1.2, 1.3)
> 51.88	2900	20198	14.4	1.3 (1.3, 1.4)
Median property value ($US, 1990)				
> 27565	2234	20444	10.9	Reference
> 23977 to ≤ 27565	2499	19551	12.8	1.2 (1.1, 1.2)
> 17251 to ≤ 23977	3229	23559	13.7	1.3 (1.2, 1.3)
≤ 17251	2866	21716	13.2	1.2 (1.1, 1.3)
Percent crowding				
≤ 4.66	2949	23719	12.4	Reference
> 4.66 to ≤ 5.80	2467	20109	12.3	1.0 (0.9, 1.0)
> 5.80 to ≤ 6.82	2708	20690	13.1	1.1 (1.0, 1.1)
> 6.82	2704	20752	13.0	1.1 (1.0, 1.1)
Percent housing constructed before 1940				
≤ 16.64	2449	21833	11.2	Reference
> 16.64 to ≤ 34.12	2952	23796	12.4	1.1 (1.1, 1.2)
> 34.12 to ≤ 52.04	2610	19411	13.5	1.2 (1.1, 1.3)
> 52.04	2817	20230	13.9	1.2 (1.2, 1.3)

*(Source: 1990 US Census)

APPENDIX N

Very Low-birthweight Rate (VLBWR) per 100 live births, odds ratio, and 95% confidence interval (C.I.) for all environmental variables - Detroit, Michigan (1984 –1988)

Variable*	Number of Births < 1500 gm	Number of Live Births	% VLBWR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Percent vacant housing				
≤ 5.50	508	23814	2.1	Reference
> 5.50 to ≤ 7.16	497	19151	2.6	1.2 (1.1, 1.4)
> 7.16 to ≤ 10.30	577	21649	2.7	1.3 (1.1, 1.4)
> 10.30	560	20656	2.7	1.3 (1.1, 1.4)
Percent renter occupancy				
≤ 30.93	473	21598	2.2	Reference
> 30.93 to ≤ 40.77	542	21503	2.5	1.2 (1.0, 1.3)
> 40.77 to ≤ 51.88	567	21971	2.6	1.2 (1.0, 1.3)
> 51.88	560	20198	2.8	1.3 (1.1, 1.4)
Median property value ($US, 1990)				
> 27565	444	20444	2.2	Reference
> 23977 to ≤ 27565	521	19551	2.7	1.2 (1.1, 1.4)
> 17251 to ≤ 23977	646	23559	2.7	1.3 (1.1, 1.4)
≤ 17251	531	21716	2.5	1.1 (1.0, 1.3)
Percent crowding				
≤ 4.66	602	23719	2.5	Reference
> 4.66 to ≤ 5.80	497	20109	2.5	1.0 (0.9, 1.1)
> 5.80 to ≤ 6.82	542	20690	2.6	1.0 (0.9, 1.2)
> 6.82	501	20752	2.4	1.0 (0.8, 1.1)
Percent housing constructed before 1940				
≤ 16.64	493	21833	2.3	Reference
> 16.64 to ≤ 34.12	588	23796	2.5	1.1 (1.0, 1.2)
> 34.12 to ≤ 52.04	509	19411	2.6	1.2 (1.0, 1.3)
> 52.04	552	20230	2.7	1.2 (1.1, 1.4)

*(Source: 1990 US Census)

APPENDIX O

Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Demographic Variables - Detroit, Michigan (1984 -1988)

Variable	Infant Deaths	Live Births	IMR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Race of Infant (Field 37)				
White (1)	218	19700	11.1	Reference
Other Asian or Pacific Islander (0)	3	537	5.6	0.5 (0.2, 1.6)
Black (2)	1047	64544	16.2	1.5 (1.3, 1.7)
American Indian (3)	4	205	19.5	1.8 (0.7, 4.8)
Chinese (4)	1	72	13.9	1.3 (0.2, 9.1)
Japanese (5)	0	17	0.0	-
Filipino (6)	0	122	0.0	-
Hawaiian (7)	1	23	43.5	4.1 (0.6, 30.3)
Other Non-white (8)	1	24	41.7	3.8 (0.5, 28.0)
Unknown (9)	1	45	22.2	2.0 (0.3, 14.8)
Maternal age				
17 – 34	1117	75765	1.5	Reference
≤ 16	84	4456	1.9	1.3 (1.0, 1.6)
≥ 35	74	5049	1.5	1.0 (0.8, 1.3)
Gender of Infant				
Female (2)	525	41736	12.6	Reference
Male (1)	746	43529	17.1	1.4 (1.2, 1.5)
Unknown	4	5	800.0	63.6 (17.0, 237.5)
Percent of population black*				
≤ 65.01	279	22053	12.7	Reference
> 65.01 to ≤ 86.95	305	21215	14.4	1.1 (1.0, 1.3)
> 86.95 to ≤ 95.18	359	20930	17.2	1.4 (1.2, 1.6)
> 95.18	332	21072	15.8	1.3 (1.1, 1.5)
Percent of population ≤ 15 years old*				
≤ 23.28	337	21324	15.8	Reference
> 23.28 to ≤ 25.05	335	22141	15.1	1.0 (0.8, 1.1)
> 25.05 to ≤ 27.80	287	21490	13.4	0.9 (0.7, 1.0)
> 27.80	316	20315	15.6	1.0 (0.8, 1.2)
Percent of population ≥ 65 years old*				
≤ 9.06	302	20053	15.1	Reference
> 9.06 to ≤ 10.75	270	19360	14.0	0.9 (0.8, 1.1)
> 10.75 to ≤ 15.50	314	22413	14.0	0.9 (0.8, 1.1)
> 15.50	341	20090	17.0	1.1 (1.0, 1.3)

*(Source: 1990 US Census)

APPENDIX P

Neonatal Mortality Rate (NMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Demographic Variables - Detroit, Michigan (1984 – 1988)

Variable	Neonatal Deaths	Live Births	NMR	Mantel-Haenszel Chi-square Odds Ratio (95% C.I.)
Race of Infant				
White (1)	122	19700	6.2	Reference
Other Asian or Pacific Islander (0)	2	537	3.7	0.6 (0.2, 2.4)
Black (2)	629	64544	9.8	1.6 (1.3, 1.9)
American Indian (3)	4	205	19.5	3.2 (1.2, 8.6)
Chinese (4)	1	72	13.9	2.2 (0.3, 16.3)
Japanese (5)	0	17	-	-
Filipino (6)	0	122	-	-
Hawaiian (7)	0	4	-	-
Other Non-white (8)	0	24	-	-
Unknown (9)	1	45	22.2	3.6 (0.5, 26.2)
Maternal age				
17 – 34	657	75765	0.9	Reference
≤ 16	47	4456	1.1	1.2 (0.9, 1.6)
≥ 35	55	5049	1.1	1.3 (1.0, 1.7)
Gender of Infant				
Female (2)	315	41736	7.6	Reference
Male (1)	440	43529	10.1	1.3 (1.2, 1.6)
Unknown	4	5	800.0	106.0 (28.3, 396.6)
Percent of population black*				
≤ 65.01	181	22053	8.2	Reference
> 65.01 to ≤ 86.95	180	21215	8.5	1.0 (0.8, 1.3)
> 86.95 to ≤ 95.18	199	20930	9.5	1.2 (1.0, 1.4)
> 95.18	199	21072	9.4	1.2 (0.9, 1.4)
Percent of population ≤ 15 years old*				
≤ 23.28	189	21324	8.9	Reference
> 23.28 to ≤ 25.05	209	22141	9.4	1.1 (0.9, 1.3)
> 25.05 to ≤ 27.80	182	21490	8.5	1.0 (0.8, 1.2)
> 27.80	179	20315	8.8	1.0 (0.8, 1.2)
Percent of population ≥ 65 years old*				
≤ 9.06	167	20053	8.3	Reference
> 9.06 to ≤ 10.75	175	19360	9.0	1.1 (0.9, 1.3)
> 10.75 to ≤ 15.50	200	22413	8.9	1.1 (0.9, 1.3)
> 15.50	185	20090	9.2	1.1 (0.9, 1.4)

*(Source: 1990 US Census)

APPENDIX Q

Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Economic Variables - Detroit, Michigan (1984 – 1988)

Variable*	Infant Deaths	Live Births	IMR	Chi-square Odds Ratio (95% C.I.)
Homes with at least one car (%)				
≥ 35.36	307	22162	13.9	Reference
< 35.36 to ≥ 32.08	322	22702	14.2	1.0 (0.9, 1.2)
< 32.08 to ≥ 26.70	309	19710	15.7	1.1 (1.0, 1.3)
< 26.70	337	20696	16.3	1.2 (1.0, 1.4)
Median household income ($1990)*				
≥ 25405	275	22330	12.3	Reference
< 25405 to ≥ 17348	296	21164	14.0	1.1 (1.0, 1.3)
< 17348 to ≥ 12174	345	22728	15.2	1.2 (1.1, 1.5)
< 12174	359	19048	18.9	1.5 (1.3, 1.8)
Households with family income above 150% of federal poverty level (%)*				
≥ 66.06	279	22849	12.2	Reference
< 66.06 to ≥ 54.17	315	21607	14.6	1.2 (1.0, 1.4)
< 54.17 to ≥ 44.73	316	20918	15.1	1.2 (1.1, 1.5)
< 44.73	365	19896	18.4	1.5 (1.3, 1.8)
Percent female head of household*				
≤ 27.09	286	22377	12.8	Reference
> 27.09 to ≤ 33.42	330	21592	15.3	1.2 (1.0, 1.4)
> 33.42 to ≤ 37.07	337	20417	16.5	1.3 (1.1, 1.5)
> 37.07	322	20884	15.4	1.2 (1.0, 1.4)
Maternal education				
> 12 years	249	22069	11.3	Reference
12 years	463	32915	14.1	1.3 (1.1, 1.5)
< 12 years	521	29787	17.5	1.6 (1.3, 1.8)
Percent of adult population without high school education*				
≤ 69.00	305	22290	13.7	Reference
> 69.00 to ≤ 70.67	293	21185	13.8	1.0 (0.9, 1.2)
> 70.67 to ≤ 74.08	323	21805	14.8	1.1 (0.9, 1.3)
> 74.08	354	19990	17.7	1.3 (1.1, 1.5)

*(Source: 1990 US Census)

APPENDIX R

Neonatal Mortality Rate (NMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Economic Variable - Detroit, Michigan (1984 – 1988)

Variable	Infant Deaths	Live Births	NMR	Chi-square Odds Ratio (95% C.I.)
Homes with at least one car (%)*				
≥ 35.36	187	22162	8.4	Reference
< 35.36 to ≥ 32.08	206	22702	9.1	1.1 (0.9, 1.3)
< 32.08 to ≥ 26.70	181	19710	9.2	1.1 (0.9, 1.3)
< 26.70	185	20696	8.9	1.1 (0.9, 1.3)
Median household income ($1990)*				
≥ 25405	168	22330	7.5	Reference
< 25405 to ≥ 17348	190	21164	9.0	1.2 (1.0, 1.5)
< 17348 to ≥ 12174	199	22728	8.8	1.2 (1.0, 1.4)
< 12174	202	19048	10.6	1.4 (1.2, 1.7)
Households with family income above 150% of federal poverty level (%)*				
≥ 66.06	172	22849	7.5	Reference
< 66.06 to ≥ 54.17	198	21607	9.2	1.2 (1.0, 1.5)
< 54.17 to ≥ 44.73	178	20918	8.5	1.1 (0.9, 1.4)
< 44.73	211	19896	10.6	1.4 (1.2, 1.7)
Percent female head of household*				
≤ 27.09	175	22377	7.8	Reference
> 27.09 to ≤ 33.42	208	21592	9.6	1.2 (1.0, 1.5)
> 33.42 to ≤ 37.07	194	20417	9.5	1.2 (1.0, 1.5)
> 37.07	182	20884	8.7	1.1 (0.9, 1.4)
Maternal education				
> 12 years	158	22069	7.2	Reference
12 years	288	32915	8.8	1.2 (1.0, 1.5)
< 12 years	277	29787	9.3	1.3 (1.1, 1.2)
Percent of adult population without high school education*				
≤ 69.00	189	22290	8.5	Reference
> 69.00 to ≤ 70.67	186	21185	8.8	1.0 (0.8, 1.3)
> 70.67 to ≤ 74.08	187	21805	8.6	1.0 (0.8, 1.2)
> 74.08	197	19990	9.9	1.2 (1.0, 1.4)

*(Source: 1990 US Census)

APPENDIX S

Infant Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Environmental Variables - Detroit, Michigan (1984 – 1988)

Variable*	Infant Deaths	Live Births	IMR	Chi-square Odds Ratio (95% C.I.)
Percent vacant housing				
≤ 5.50	281	23814	11.8	Reference
> 5.50 to ≤ 7.16	277	19151	14.5	1.2 (1.0, 1.5)
> 7.16 to ≤ 10.30	363	21649	16.8	1.4 (1.2, 1.7)
> 10.30	354	20656	17.1	1.5 (1.2, 1.7)
Percent renter occupancy				
≤ 30.93	258	21598	12.0	Reference
> 30.93 to ≤ 40.77	311	21503	14.5	1.2 (1.0, 1.4)
> 40.77 to ≤ 51.88	361	21971	16.4	1.4 (1.2, 1.6)
> 51.88	345	20198	17.1	1.4 (1.2, 1.7)
Median property value ($US, 1990)				
> 27565	257	20444	12.6	Reference
> 23977 to ≤ 27565	657	43110	15.2	1.2 (1.1, 1.4)
> 17251 to ≤ 23977	354	23559	15.0	1.2 (1.0, 1.4)
≤ 17251	361	21716	16.6	1.3 (1.1, 1.6)
Percent crowding				
≤ 4.66	338	23719	14.3	Reference
> 4.66 to ≤ 5.80	304	20109	15.1	1.1 (0.9, 1.2)
> 5.80 to ≤ 6.82	315	20690	15.2	1.1 (0.9, 1.3)
> 6.82	318	20752	15.3	1.1 (0.9, 1.3)
Percent housing constructed before 1940				
≤ 16.64	305	21833	14.0	Reference
> 16.64 to ≤ 34.12	315	23796	13.2	1.0 (0.8, 1.1)
> 34.12 to ≤ 52.04	306	19411	15.8	1.1 (1.0, 1.3)
> 52.04	349	20230	17.3	1.2 (1.1, 1.4)

*(Source: 1990 US Census)

APPENDIX T

Neonatal Mortality Rate (IMR) per 1,000 Live Births, Odds Ratio, and 95% Confidence Interval (C.I.) for all Environmental Variables - Detroit, Michigan (1984 – 1988)

Variable*	Infant Deaths	Live Births	NMR	Chi-square Odds Ratio (95% C.I.)
Percent vacant housing				
≤ 5.50	186	23814	7.8	Reference
> 5.50 to ≤ 7.16	165	19151	8.6	1.1 (0.9, 1.4)
> 7.16 to ≤ 10.30	207	21649	9.6	1.2 (1.0, 1.5)
> 10.30	201	20656	9.7	1.3 (1.0, 1.5)
Percent renter occupancy				
≤ 30.93	174	21598	8.1	Reference
> 30.93 to ≤ 40.77	187	21503	8.7	1.1 (0.9, 1.3)
> 40.77 to ≤ 51.88	213	21971	9.7	1.2 (1.0, 1.5)
> 51.88	185	20198	9.2	1.1 (0.9, 1.4)
Median property value (SUS, 1990)				
> 27565	162	20444	7.9	Reference
> 23977 to ≤ 27565	388	43110	9.0	1.1 (0.9, 1.4)
> 17251 to ≤ 23977	201	23559	8.5	1.1 (0.9, 1.3)
≤ 17251	209	21716	9.6	1.2 (1.0, 1.5)
Percent crowding				
≤ 4.66	184	23719	7.8	Reference
> 4.66 to ≤ 5.80	203	20109	10.1	1.3 (1.1, 1.6)
> 5.80 to ≤ 6.82	195	20690	9.4	1.2 (1.0, 1.5)
> 6.82	177	20752	8.5	1.1 (0.9, 1.4)
Percent housing constructed before 1940				
≤ 16.64	195	21833	8.9	Reference
> 16.64 to ≤ 34.12	192	23796	8.1	0.9 (0.7, 1.1)
> 34.12 to ≤ 52.04	171	19411	8.8	1.0 (0.8, 1.2)
> 52.04	201	20230	9.9	1.1 (0.9, 1.4)

*(Source: 1990 US Census)

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