Socio-economic and environmental differentials, and mortality in a developing urban area (Belo Horizonte – Brazil)

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by

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To Lili, Júlio
and anjinho

" I have also thought of a model city from which I deduce all the others... It is a city made only of exceptions, exclusions, incongruities, contradictions. If such a city is the most improbable, by reducing the number of abnormal elements, we increase the probability that the city really exists. So I have only to subtract exceptions from my model, and in whatever directions I proceed, I will arrive at one of the cities which, always as an exception, exist. But I cannot force my operation beyond a certain limit: I would achieve cities too probable to be real" (Italo Calvino)

Abstract

Studies on health inequalities on developing cities are scarce. They have mainly focused on infant and child mortality and life expectancy at birth. Studies of adult mortality and cause-specific studies have seldom been carried out.

An ecological study was performed in order to investigate the relationship between mortality due to all causes of death, infectious diseases, combined illness of diarrhoea, pneumonia and malnutrition, external causes, homicides, and motor vehicle traffic accidents, and socio-environmental conditions in a developing city, Belo Horizonte in Brazil.

Death certificates relating to 1994 were processed. A total of 10,558 certificates were geocoded according to 75 geographical areas. The areas were classified according to the income of the head of family (or female illiteracy when appropriate), and plausible routinely environmental factors. In the study of mortality due to infectious diseases, water, sanitation, crowding, and rubbish collection were tested. Among the external causes, the study focused on homicide and motor vehicle traffic accidents, testing the effect of public illumination, crowding and the average time for police response to a phone call. Analytical and descriptive techniques were used in the study. Mortality rate (MR) ratios were estimated using random effects Poisson regression.

A high correlation was found between socio-economic and environmental variables. These correlated to the distribution of mortality rates across the areas. Shantytown areas (the favelas) presented higher risk of mortality than non-favela areas. Infectious diseases, homicide, and combined illness of diarrhoea, pneumonia and malnutrition (under 5 years old) presented MR ratios of 1.59, 2.05, 1.62, respectively. All of them presented p-values for trend <0.00. Deaths due to all causes presented 1.12 ($p=0.04$).

Adverse socio-economic and environmental conditions are associated with higher rates of specific cause of death. Deprived areas encompass highest vulnerable groups. The use of routine data in developing countries can be used to measure the inequalities in health, helping build up more adequate urban and health policies.

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List of acronyms

AIDS	Acquired Immune Deficiency
BH	The City of Belo Horizonte
BMA	British Medical Association
CAPES	Fundação Coordenação de Aperfeiçomento de Pessoal de Nível Superior
CENEPI	Centro Nacional de Epidemiologia [National Centre of Epidemiology]
CI	Confidence Interval
DATASUS	Departamento de Informática do Sistema Único de Saúde [Computing Department of the Unified Health System]
DETRAN	Departamento Nacional de Trânsito [National Traffic Department]
FJP	Fundação João Pinheiro [João Pinheiro Foundation]
FNS	Fundação Nacional de Saúde [National Foundation of Health]
GIS	Geographic Information System
HABITAT	United Nations Centre for Human Settlements
HIV	Human Immunodeficiency Virus
IBGE	Intituto Brasileiro de Geografia e Estatística [Brazilian Institute of Geography and Statistics]
ICD	International Classification of Diseases
IQVU	Índice de Qualidade de Vida Urbana [Index of Urban Quality of Life]
IUSSP	International Union for the Scientific Study of Population
MR	Mortality Rate
MS	Ministério da Saúde [Ministry of Health of Brazil]
MVTA	Motor Vehicle Traffic Accidents
MW	Minimum Wage
P-value	Probability Value
PAHO	Pan American Health Organization
PRODABEL	Empresa de Informática e Informação do Município de Belo Horizonte [Company of Informatics and Information of Belo Horizonte]
PU	Planning Unit
SMR	Standardised Mortality Rate
SUS	Sistema Único de Saúde [Unified Health System]
UFMG	Universidade Federal de Minas Gerais [Federal University of Minas Gerais]
WHO	World Health Organization
YLL	Years of Life Lost

Acknowledgements

All doctoral theses tell at least two stories. One is related to their contents. The other is the story of the personal motivations, how each line was conceived, and the gains and losses that occurred along the journey to the *Viva Voce*. In this section, part of this personal journey is recovered in mentioning the contributors.

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Chapter 1 - Introduction

1.1 Introduction

Urbanisation is increasing rapidly in the world. In 1995, over 40 % of the total global human population was urban. The urban population of developing countries is larger than the combined populations of Europe, Japan and USA (HABITAT, 1996).

During the last 20 years, urban areas have faced rapid and massive population growth, an increase in the density of human settlement, poverty, and traditional risks from industrialisation, transport and energy production. The poorer populations have witnessed the inability of the financial and administrative capacity of the cities to provide for their needs (ROSSI-ESPAGNET ET AL, 1991).

It seems that in most of the cities in developing countries, environmentally related diseases or hazards are one of the major causes of illness, accidents and premature death (SATTERTHWAITE, 1993).

Epidemiologists have also given important contributions to unveil the association between socio-economic inequality and health. For example, unequal income distribution has been shown to be associated with mortality trends in the USA (KAPLAN ET AL, 1996, KENNEDY ET AL, 1996), and with life expectancy in Britain (BEN-SHLOMO ET AL, 1996). Another example, according to KAPLAN ET AL (1996) relative income seems to be associated with homicide, and also with low birth weight in the USA. BREILH ET AL (1983) found an association between social class and infant mortality in Quito (Ecuador).

However, the mainstrain epidemiology has not found a place for health inequality determinants in their frameworks (MCMICHAEL, 1999). Those, who have tried to investigate urban health inequality, have been challenged by important scientific questions.

The very first one: what is socio-economic inequality and how to measure it? Concepts such as poverty and socio-economic inequality are subjects of controversy in social science and public health literature. In fact neither poverty nor socio-economic inequality can be directly assessed (GORDON, 1995).

Different strategies have been used to measure socio-economic inequality. If only UK geographical studies of socio-economic inequality were considered, there are at least 6 different indices, containing 20 different variables in the recent public health studies (MORRIS AND CASTAIRS, 1991, and GORDON, 1995). The multiplicity of indices and variables used for this purpose suggests that there are multiple inequalities to be measured (MANOR ET AL, 1997).

In developing country cities, such Latin American cities, intra-urban variation studies are an important way to investigate the socio-economic and environmental differentials, and mortality profiles. In Brazil, most epidemiological studies of inequalities in health have used ecological analysis, based on limited available data. Occupational class and ethnicity, most used socio-economic variables in UK and USA, have not been collected by the population census, which is the most used source for studying inequality on health.

An intrinsic dimension of the intra-urban inequality is environmental inequality. SAGAR (1994) argued that it must be logical that the poorer seem to be less healthy than the richer people, and that "the physical environment is one function of the social environment" (p. 362). However some questions demand further exploration: What social and environmental factors are related to health inequality? What are the links between socio-economic and environmental factors? Which are the most vulnerable groups in developing country cities? And in this context, what are the health policy implications of health inequality?

This research aims to contribute to the epidemiological debate, studying a health inequality pattern in a developing city. It will focus on the contribution of feasible socio-economic and environmental risk factors, by estimating the risk for the most vulnerable populations.

This thesis will explore two aspects of the double burden of diseases[1] in a developing country city (Belo Horizonte, Brazil), through analysing the association between mortality, and socio-economic and physical environmental factors. Double burden of disease relates to being exposed simultaneously to modern (infectious) and old patterns (chronic) of disease (HARPHAM, 1988).

Deaths due to infectious diseases and the combined deaths due to diarrhoea, pneumonia and malnutrition (under 5 years at death) will be analysed as tracers of the old pattern of disease. Deaths due to external causes of death, homicides, and motor vehicle traffic accidents (MVTA) will be analysed as tracers of the new pattern of disease.

1.2 Policy relevance

The issue of urban inequalities in health has emerged internationally as an important item in the public health agenda. Recently, the concept of health inequality has been recognised in the official discourse of local and international health agencies[2].

The Independent Inquiry into Inequalities in Health Report (1998) in the UK has recommended that all policies related directly or indirectly to health should take into account their possible impacts on health inequality, and should be formulated in order to contribute in reducing these inequalities. This recommendation implies conceptual and methodological development of health inequality studies. It also implies further investigations, which cover the variety of scenarios and the multiple health problems related to that question.

When thinking about developing country cities, that recommendation should imply two additional demands: policy for tackling double-burden disease pattern and methods for accessing health inequality with scarce data sources.

[1] A mortality pattern that juxtaposes diseases associated with both modern and old risks.
[2] See Department of Health (1999), *Reducing health inequalities:* an action report and WHO (1999), *Removing obstacles to healthy development.*

In that context, the health systems should cover a broad spectrum of services that allow for diagnosing and treating acute and chronic diseases. Although, composition and allocation of these resources depend on state financial capability, technical criteria and political interests. The lack of consistent information and parameters for health evaluation tends to reduce the contribution of the technical approach in the policymaking process.

This thesis intends to contribute to urban health policy by providing an epidemiological approach to identify health needs, urban health risks and vulnerable populations in developing country cities. In addition, it also aims to contribute towards: improving the knowledge about health inequality in a developing city; adding evidence about the relationship of socio-economic and environmental variables, and mortality; showing the connection of infectious diseases and external causes of death in shanty towns; presenting an analysis based on available routine data, that can be replicated in great part of Latin American cities; providing an alternative technical criteria that can be useful in monitoring the impacts of policies designed to reduce health inequality in a developing city. It builds on other researches in this field by applying the most up to date methods of inequality analysis.

Those issues are particularly important to Brazil because health public services provision is almost entirely municipal. Facilities, and therefore access, related to health are unequally distributed between and within the cities. MUSGROVE (1998) points out the lack of indicators between health resource allocation and health needs, suggesting that the distribution of health funds is unfair within Brazil.

1.3 Structure of the thesis

This thesis is presented in 7 chapters. The remainder of this chapter – *Introduction* – sets out the structure of the thesis.

Chapter 2 – *Literature Review* – presents in first part the rationale for assessing intra-urban health inequalities in a Brazilian city. In the second part, it presents case definition in relation to infectious diseases and external causes of death.

Chapter 3 – *Hypothesis and Objectives* – presents the study hypothesis drawn from the literature review, and sets up the aim and objectives of the study.

Chapter 4 – *Methods* – describes aspects of the city of Belo Horizonte, data used in the research (mortality, population and exposure data), and the geographical units used for the study. Issues concerning plausibility, ecological fallacy, misclassification of exposure and outcome variables, availability of routine data, and the use and limitations of ecological studies are also debated in this chapter. Finally, the chapter presents the study design and the analysis strategy.

Chapter 5 – *Results I* – gives the results obtained through descriptive and analytical techniques, presenting the distribution of mortality across the geographical units within the city. Maps related to socio-economic and environmental variables are presented as a complement of descriptive techniques.

Chapter 6 – *Results II* - gives the results obtained through descriptive and analytical techniques, presenting the distribution of mortality between two geographical group of areas: favelas (shanty towns) and non-favelas areas.

Chapter 7 – *Discussion, policy implications and recommendations* – addresses methodological issues related to error, bias and confounders in the study. Social and environmental inequality determinants and epidemiological transition implications are discussed. Health policy implications are further debated in this chapter. Finally, specific recommendations are made in relation to improving mortality and geographical data for ecological studies in Brazil and Belo Horizonte.

Annex 1 contains a table presenting total population and population under 5, and deaths due to selected causes for the planning units. Annex 2 contains the methods used to match planning units and census tracts networks. Annex 3 contains a table comparing the mortality data processed by Fundação João Pinheiro and the mortality data processed in this research. Annex 4 contains demographic techniques used for estimating population for each Planing Unit. Annex 5 presents maps of socio-economic and environmental characteristics of the planning units. Finally, Annex 6 presents maps of Standardised Mortality Rates for the planning units.

Chapter 2 - Literature Review

2.1 Introduction

This review was organised according to the following topics related to the scope of the research: socio-economic, environmental and health inequalities in urban areas; urban environment and heath; urbanisation in Latin America; Brazilian studies on health intra-urban inequalities; cause-specific mortality and urban inequality in health; infectious diseases, and injuries and violence.

The review will focus on mortality studies because, in developing countries, they are easily available and have better quality than morbidity data. Infectious diseases, and injuries and violence were chosen to describe the intra-urban variations in mortality. The former is commonly associated with an older or undeveloped pattern of mortality, whereas the latter is generally associated with an emergent pattern of mortality. Both groups of diseases are closely related to socio-economic and physical environmental factors.

2.2 Socio-economic and health inequalities in urban areas, and urban environment: concepts

Social inequality can be defined as the unequal distribution of material and non-material goods and services among social groups (WOOD AND CARVALHO, 1988). Health or ill health is also unequally distributed within society (TOWNSEND AND DAVIDSON, 1982). Inequality in health can be defined as the description of the uneven distribution of disease risk and treatments within the population (STEPHENS, 1996).

The problems related to health inequality have different patterns across countries. They also can be aggravated according to the demographic components, the environment management, health sector capability, and economic and political dynamics.

Problems associated with the built environment and overcrowding are sometimes defined as the "urban crisis" (ROSSI-ESPAGNET ET AL, 1991). Even in developed countries, with very low rates of population growth, health problems are related to: drug abuse, crime, mental illness, vandalism, problems related to changes in diet and residential patterns, and the capacity to deal with produced waste (ROSSI-ESPAGNET ET AL, 1991). But this crisis cannot be compared to the heavy burden faced by the cities in developing countries where the environmental changes have produced patterns of health problems typical to developing country cities juxtaposed with those of developed cities.

HARPHAM ET AL (1988) suggested three groups of factors which might be linked to urban inequalities in heath in developing country cities: I) *Direct problems of poverty*, which encompass unemployment, low income, limited education, and inadequate diet. II) *Environmental problems* which include overcrowding, poor housing, lack of infrastructure facilities, air and water pollution, and daily exposure to infectious diseases. And III) *Psychosocial problems* such as stress, instability, and insecurity.

In developing country cities, environmentally related diseases or hazards are usually one of the major causes of illness, accidents and premature death (SATTERTHWAITE, 1993). The health hazards associated with the urban environments are classified according to SATTERTHWAITE (1993) as: biological disease-causing agents (pathogens), chemical pollutants, a shortage of or lack of access to particular natural resources, and physical hazards. Three other factors have an indirect influence on health: the built environment with negative consequences on people's health, natural resource degradation, and large scale environment degradation. This unhealthy urban context has called the attention of the contemporary epidemiology.

Contemporary epidemiology has studied the urban health risks in a limited way. In practical terms epidemiology has directed its cannons toward the potential sources of risks related to: the environment, the societies, the communities, the families and the individuals. "Black box" studies[3] have been carried out in order to study the association between available independent variables and dependent ones. However, that pragmatic view does not prevent the epidemiology to turn a blind eye to the many factors related to a unequal societal dimension of life. Indeed, socio-economic and environmental inequalities have been out of the scope of study of traditional epidemiology (KRIEGER AND FEE, 1994).

No one seems to doubt the relationship between unfavourable socio-economic conditions and illness. The challenge (and the controversy) is to define the role of the social determinants of health within the "causal web". KRIEGER (1994) has pointed out that "biomedical individualism" has dominated the causal theory in contemporary epidemiology. The social determinants have been understudied and hence underreported.

WILKINSON (1996) considered that the factors, which interfere in the process of ill health, work at an individual or at a societal level. Some factors that operate on a societal level may not be confirmed on the level of individual analysis. He argues that individual and societal analysis may have different but "equally valid" results.

WILKINSON also (1992, 1996) suggested that relative socio-economic position may be more strongly associated to the health of the population rather than absolute socio-economic status[4]. The author considers that inequality is relative within and between societies, and it can be assessed through an individual and societal level. Moreover, the health of society is determined by the socio-economic context through the effect of psychosocial factors.

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[3] Black box epidemiology has many supporters because "even without a clear understanding of mechanism [of the disease], such observations may provide the basis to modify exposures in order to prevent diseases" (SAVITZ, 1999).

[4] "What makes understanding health sociologically important is that many modern health problems reflect people's subjective experience of the circumstances in which they live...The psychological repercussions of social circumstances are known to contribute to morbidity and mortality from wide range of conditions. The implication is that the disease profile of different societies, and different status groups within populations, tell us something about the subjective impact of social and economic systems" (WILKINSON, 1996. p. 23).

Some studies have tried to produce a research framework encompassing both socio-economic and biological factors. In 1984, MOSLEY AND CHEN proposed a framework[5] for the study of child survival in developing countries. They considered the influence of behavioural and biological factors, and also socio-economic and demographic factors in the process that determines child survival. In this framework, the father's education is considered in the socio-economic determinant domain (distal determinant). The mother's education is considered in the proximate determinant[6] domain jointly with environmental contamination, nutrient deficiency, and injuries and violence. They consider that socio-economic variables vary as determinants of ill health, according to the role that each family member plays in child health care.

Recently, BRUNNER AND MARMOT (1999) designed a framework, placing psychological factors and health behaviour in an intermediate position between socio-economic and socio-environmental determinants, and ill health. Material factors are directly associated with health. Social and work environmental factors operate through psychological factors and health related behaviours (Figure 2-1).

Combining social-mediated behaviours with psychological factors the authors try to fill the gap present in most of the frameworks: how does the social dimension connect to the biological dimension in the ill health pathway? This seems to be the missing link in the previous proposals, such as those elaborated by KRIEGER (1994) and WHITEHEAD (1994).

However, the limitations of BRUNNER-MARMOT framework seem to be:

- The weight variation of each component is not considered. Either genetic or social, or even psychological factors can have different weight within the "causal web". Hence, they can have different roles in different diseases.

- The relationship between material factors and health behaviour factors is not clear in the framework. In fact, their connections are not present in the model at all. In the model, culture is divorced from the social structure. And finally, the category "early life" seems

[5] BOERMA (1996) listed the criticisms against Mosley-Chen's framework, such as: it favours the use of cross-sectional design and it promotes an oversimplification of the socio-economic determinants.
[6] MOSLEY-CHEN (1984) framework groups the health determinants in two levels: socioeconomic and proximate. The proximate are those which directly influence morbimortality risks, such as maternal factors, environmental contamination, nutrient deficiency, injury, prevention and medical treatment.

to be a floating one within the framework. Overall this shows the difficulty of addressing thesis of WILKINSON (1996) in conceptual terms.

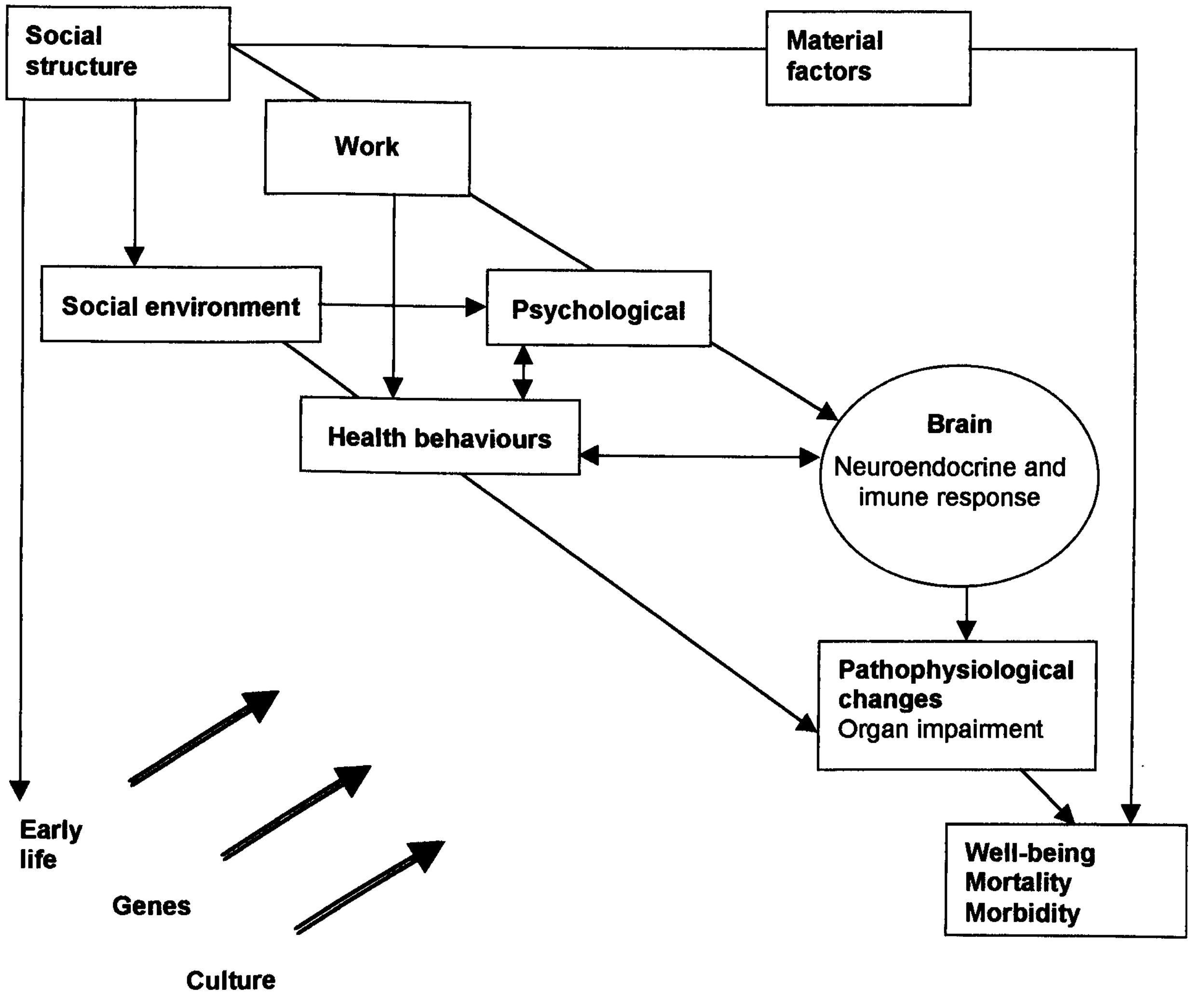

Figure 2-1 Social determinants of health according to BRUNNER AND MARMOT (1999, p. 20)

2.3 Urban environment and health

The most used concept of environment can be found in LAST (1988, p.41) as "all that which is external to the individual human host. Can be divided into physical, biological, social, cultural, etc., any or all of which can influence health status of populations".

Despite being widely used, the definition of environment can be generically applied to everything except the genome (BRADLEY ET AL, 1992). In practical terms, BRADLEY ET AL (1992) proposed an environmental taxonomy that may be associated with disease pattern (Box 2-1).

Box 2-1 An Environmental Taxonomy Related to Disease Patterns

Water-wastes complex
- Domestic water
- excreta
- drainage
- surface water
- water-related vectors
- solid wastes solid waste-related vectors
- rodents

Shelter and the built environment
- Housing
- cooking facilities
- sanitary facilities
- health care facilities
- transport system
- air pollution

Food
- food supply
- food hygiene
- markets
- slaughterhouses
- food processing plants

Other people
- crowding
- organic pollution
- trauma
- inorganic pollution

Other organisms
- domestic animals
- stock
- vectors

Weather
- temperature
- humidity
- natural disasters
- other extreme events

Source: BRADLEY ET AL (1992) *A review of environmental health impacts in developing country cities.*

In fact that taxonomy refers exclusively to physical environmental factors. Socio-environmental factors are not included in that. Socio-environmental factors refer to the components of the social relations affected by behaviour settings, organisational structure, personal-behavioural characteristics at group level, psychosocial characteristics and organisational environments, and social coercion mechanisms (COWEN ET AL, 1980). Given the complexities of these variables, they are not available from routine data and usually require a qualitative approach. That complicates the measurement of social-environmental impact assessment. These impacts are often underestimated and assessment is lacking in methodology and practice (BMA, 1998).

In developing country cities, even physical environmental variables are usually not available as routine data. This can restrict the use of some categories in an ecological analysis. Unfortunately, physical environmental hazards have not been explored much in epidemiological investigations in developing country cities (HARPHAM AND STEPHENS, 1991). In particular, the interaction between socio-economic and environmental variables have seldom been investigated in developed and developing country cities.

Some studies from developing country cities have found evidences of strong interaction between socio-economic adversity and unhealthy environment. In 1994, STEPHENS ET AL concluded from a study involving São Paulo and Accra that: "child mortality differentials are influenced by both individual socio-economic circumstances and neighbourhood conditions. Individual wealth does not fully protect individual health for those living in poor neighbourhoods...social and physical deprivation exerts a strong combined pressure which affects in different measure both adult and child mortality" (STEPHENS ET AL, 1994, p.116).

2.4 Urbanisation in Latin America

Demographic and epidemiological transitions are shaping and being shaped by urbanisation. The demographic aspects combined with the urban built environment have influenced the conditions of living and, therefore, of dying.

Fertility and mortality trends influence the age composition of populations, which, consequently, influences mortality patterns. The links between mortality patterns and population dynamics are commonly studied within the epidemiological transition theory. In

Latin American countries, three components of the population dynamics (fertility, mobility and mortality) seem to be strongly associated with urbanisation.

In Brazilian cities, decline in fertility, increase in life expectancy and rural-urban migration have contributed in the shaping of the size of the population and its age-structure. However, that process has not been homogeneous within the urban space. Furthermore, mobility has not been constant throughout the years.

In Brazil, according to the last population census in 1991, 75.5% of the population was living in urban areas (IBGE, 1992). The process of rising urbanisation started in the 1930s. MARTINE (1993a) reports that in 1940, the rural areas and cities under 20,000 inhabitants were responsible for 85% of the whole population. In 1980 this proportion had dropped to 46%. At the same time, population in cities with over 500,000 inhabitants increased from 8% to 32% of the total population. This was known as the process of metropolization[7] in which contiguous cities develop strong social, economic and political links (Santos, 1993).

However, from 1980 to 1991, the process of metropolization has decelerated and this might be due to: the decline in fertility, delayed effects of industrial deconcentration[8], attitudes related to *counter-metropolization*[9], a better distribution of the population among different sizes of cities, and the cumulative effects of the occupation of Amazonian frontiers on population deconcentration (MARTINE, 1994, 1993a, 1993b). The decline in fertility has produced direct and indirect[10] effects on migrant populations.

In 1991, the growth rates of Belo Horizonte City, like São Paulo and Rio de Janeiro, were lower than that expected by the government. MARTINE (1993a) and COSTA (1994) explain this phenomenon as a consequence of migrations from the centre towards peripheral cities or outside the metropolitan region.

[7] Some metropolises establish governmental offices responsible for the administration of general or specific issues. They form a metropolitan region, which has a main city from which its name derived (SANTOS, 1993).
[8] " In Brazil, this process is associated with the location of new [industrial] plants and not the relocation of old ones" (MARTINE, 1993b, p.129).
[9] Counter-metropolization happens when the population growth in the metropolitan regions is lower than the outside areas (MARTINE, 1993a)
[10] The direct effects mean the decline of childbirth in rural areas. Indirect effects are the consequence of the new contraceptive patterns being adopted by migrants living in the cities.

According to SKELDON (1990) Brazil is completing the late transitional phase of mobility transition[11]. This means that while on the one hand, the movements from the countryside to cities still tends to continue, though in smaller proportions; on the other hand, the interurban and intra-urban mobility is still increasing. Although the mobility from the country areas to the cities has declined because of the reduction of the rural population, the inter-urban mobility has not reduced in its intensity (SKELDON, 1990).

MARTINE (1994) considers that Brazil is slowing down in its mobility and demographic transitions. However, when analysing the social stratification within the city, the relationship between urbanisation and socio-economic development has complex components:

" The cities multiplied and concentrated urban resources. Urban industrial growth stimulated an increase in levels of education, the proletarization of labour-force, and the expansion of non-manual sectors. It led to changes in customs, and, in general, to attitudes favourable to economic growth and to social change. On the other hand, this same urban growth did little to diminish the existing polarisation of social structure, either in terms of income or labour conditions, as shown by persistence of non-waged forms of labour ... and highly skewed income distributions." (DE OLIVEIRA AND ROBERTS, 1996, pp 253-254)

The social distribution of populations within the cities varies according to rural-urban migration, the price of land in the cities, and the emergence of industrial poles (COSTA, 1994). Crowded cities are directly linked to economic concentration and diversification.

Historically, the cities have become dense spaces for the production of goods, population reproduction, and consumption of products. Living areas can also be considered as a good. Economic and symbolic values vary within interurban spaces (BREILH ET AL, 1983). Expensive areas usually have the highest standards of architecture and services structure.

In Brazilian cities, as in any Latin American city, the spatial distribution of the population varies among cities. While in São Paulo the poorest population, since its foundation, has been pushed towards the periphery, in Rio de Janeiro and Belo Horizonte they historically occupied the hill sides of the city, including those areas close to the centre. Nowadays, the

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[11] ZELINSKY (1971) considered that mobility transition as a relationship between migration and demographic transition. The main hypothesis is that there are historical regularities in personal mobility, being related to the modernisation process.

low-income groups tend to occupy other smaller cities within the Belo Horizonte Metropolitan Area (PBH, 1995).

Squatter settlements[12], as a form of location for the poorest populations, are present in all big Latin American cities. SKELDON (1990) emphasises that it is a 'solution or at least a part of a solution' to the demand for households where the government and private sector cannot respond[13]. He argued that the social cost to assist the population in order to build households is smaller than preventing or banishing illegal occupations.

In Latin America, low-income settlements have different names. HARPHAM ET AL (1988) enlisted some of them: *barriadas* and *barrios marginales* (Peru), *colonias proletarias* and *jacales* (Mexico), *poblaciones* and *callampos* (Chile), and *villas miseria* (Argentina). In Brazil (Rio and Belo Horizonte cities), the low-income settlements are named *favelas*.

Usually, the *favelas* are located in the most polluted and unattractive living areas within the city (COSTA, 1994). These conditions define the price of the land market and make it an unattractive option for the middle-class and wealthy groups.

2.4.1 The favelas

In the beginning of the 20th Century, the expression *favela* became a general denomination in Brazilian Portuguese for poor settlement in the hills. Its origin comes from the areas next to the battlefield of the War of Canudos. This was a popular insurrection headed by a messianic ex-builder, Antonio Vicente Mendes Maciel (The Counsellor). He settled a primitive Christian community in desert area of the State of Bahia. Canudos was next to a hill named favela (morro Favela). The Brazilian Army massacred the rebels in 1897. The conflict was

[12] For SKELDON (1990) the concept of a squatter settlement implies "a particular tenure status: they are illegal in the sense that the residents neither own nor rent the land on which they build their dwelling" (p. 236). In the Brazilian context it also means a group or a household created by the government without adequate urban infrastructure, and without defined property rights. Some squatters do not have even sewage or drainage services and others were created as a consequence of the invasion of public areas initially designed to be schools, health or community centres (PBH, 1995).

[13] "In developing countries the level of urbanisation is expected to increase to 39.5% by the end of this century and up to 56.9% by 2025. The number of people living in slums and shanty towns represent about one-third of the people living in cities in developing countries" (HARPHAM AND STEPHENS, 1991).

covered with fervour by Rio media that start to apply the name favela to the poor settlements of Rio (ZALUAR AND ALVITO, 1999).

In Belo Horizonte, favela is also used to define the squatter settlements on the steep hillsides. Nowadays, the term defines an occupation of public or private areas, where precarious constructions are built. The favelas have precarious provision of urban infrastructure and public services.

Most of the settlements occupy areas not planned nor adequate for habitation, such as green areas or lake surroundings, areas planned to be used in the transport network, and areas prone to landslide (PBH, 1995). In favelas, a deforestation process has further diminished the retention capacity of the soil and stability of the slopes, increasing the risk of landslide (EDELMAN ET AL, 1997).

The favelas of Rio and Belo Horizonte have produced a unique urban morphology. EDELMAN ET AL (1997) have described the physical characteristics of the favelas as:

"They have a complex urban morphology and built-up environment. The access roads are very narrow and follow any alignment; the plots are irregular in form and size, and there is rarely any open space for leisure. There is no tenure formalisation either, except where the local government is carrying out and upgrading projects of formalisation. The dwellings are built with wood or ceramic brics, but the percentage of wood-based dwellings has decreased rapidly over the last 10 years (p. 9)."

In addition to environmental problems, the favelas face violence and crime. In general, violence and crime are higher in the favelas than in the rest of the city, being associated with drugs and weapons smuggling, and other criminal activities.

In 1994, the Municipality of Belo Horizonte identified 139 settlements as favelas (PBH, 1995). In the last decade did not produce new favelas but grow and consolidate the older ones. In 1991, the favelas' population accounts for 21% of the whole population, covering only 6% of the area of the city. The favelas vary in size of the population. In 1991, favelas such Morro das Pedras had population over 21,000 and Cafezal around 27,000 (SMPL, 1996).

2.5 Health and intra-urban inequalities: Brazilian studies

Urbanisation is associated with the rise of health levels of the Latin American population (CHAKIEL AND PLAUT, 1996). However, if on the one hand the urban citizens are more likely to be reached by new health and hygiene policies, on the other hand they are also exposed to new risks related to industrial sources, violence and psychosocial factors. This means that a contradictory scenario tends to take place in the cities, especially, in developing countries. "Who you are and which part of the city you live in become major factors influencing the health and life chances of you and your family" (PHILIPS, 1993, p. S98).

Since 1940, the Brazilian urban population has faced dramatic changes in mortality patterns. When compared to rural areas, Brazilian cities present lower levels of mortality in all age groups, and lower levels of mortality due to infectious diseases. In the cities the levels of fertility have declined largely in the last 30 years as well. This suggests that the urban population has better conditions in terms of sanitation and medical care and easier access to health supplies.

However mortality rates vary within the city, suggesting that the gains of urbanisation[14] are not equally distributed among all settlers. "When urban data are disaggregated, intra-urban differences emerge to highlight inequity within the city" (HARPHAM AND REICHENHEIM, 1994, p.86). Socio-economic differences and uneven mortality patterns have been part of the urban scenario in Brazil.

Some epidemiologists and demographers have explored the links between social and economic inequalities and ill health. However, the studies are scarce and have focused on children and infants (BRADLEY ET AL, 1992).

Brazilian epidemiological studies seem to confirm HARPHAM and STEPHENS' (1991) observations of epidemiological studies worldwide. Some epidemiologists have studied intra-urban inequalities within Brazilian cities (Table 2-1). However, just recently the association between adult mortality and urban inequalities has been studied. In addition, they have

[14] Urbanisation is defined as: "Growth in the proportion of persons living in urban areas" (IUSSP, 1982). The concept varies between different countries, but in the Brazilian context it is used for areas with populations over 20.000 (MARTINE, 1993a).

followed an international trend of focusing on primary towns, such as Accra and Jakarta (McGRANAHAN AND SONGSORE, 1996), Cape Town (RIP ET AL, 1987) and Khartoum/ Omdurman (HERBERT AND HIJAZI, 1984).

Income and composite indexes are the dominant assessment technique for measuring inequalities in health intra-urban studies. From 1994 onwards, the studies have included external causes of death. However, the relationship between infectious diseases and external cause has not been studied. Infectious diseases and external causes, in special homicides, threaten the same vulnerable groups within the cities. Both causes are connected to socio-economic factors and deprived areas. Beyond the biological pathways and the proximate determinants, there are health policy implications related to improving living conditions and the environment that can affect infectious diseases and homicides.

Table 2-1 Summary of Literature on Intra-urban Differentials in Mortality in Brazilian Urban Areas

Author	Year	Location	Group	Number of areas	Findings/Comments
MONTEIRO ET AL	1980	São Paulo	Infants	55 areas	The lower income families were twofold more frequent in high infant mortality areas than in lower mortality ones. Decreasing distribution of public health facilities showed synergetic effects with income distribution.
GUIMARÃES AND FISCHMANN	1985	Porto Alegre	Infants	4 areas	The infant mortality rates increased from the centre of the city to outward. Infant mortality rates were threefold higher for shantytown dwellers than for non-shantytown ones. Perinatal conditions, pneumonia and influenza, and infectious intestinal diseases presented the greatest variations within the areas.
PAIM ET AL	1987	Salvador	Infants	76 areas	Positive correlation between proportional infant mortality and the percentage of low-income families, residence crowding, and deprived housing. No significant correlation was found between proportional infant mortality and public health facilities.
PAIM AND COSTA	1993	Salvador	Infants	76 areas	From 1980 to 1988 infant mortality has declined in all areas. However the infant mortality remained unevenly distributed within the city.
CARVALHO	1993	Rio de Janeiro	All ages	3 areas	The findings are limited because they were based on a few areas with close socio-economic profiles. However, an association was found between socio-economic conditions and infant mortality and all age-group mortality rates due to injuries and violence.
AMARANTE ET AL	1994	Rio de Janeiro	All ages	5 cities within a metropolitan area	The trends for external causes mortality rates presented a non linear increase in the four periphery cities. A decrease was observed between 1979 and 1983, succeeded by an

					increase until 1987, which was the last year observed.
STEPHENS ET AL	1994	São Paulo	All ages	56 areas	Respiratory and infectious mortality rates were fourfold greater for 0-4 years old group living in the most deprived areas against those in the same age band living wealthier areas. Homicide rates are 3 times greater among adult male (15-44 years) living in the most deprived areas as compared with those living in wealthy areas. Traffic accidents, cerebrovascular diseases, and hypertension mortality rates were twofold higher in most deprived areas than in the wealthy ones in the 45-64 years old group.
CEDEC	1996	São Paulo	All ages	96 areas	The crude homicide rate is forty-twofold greater in the top risk rank areas than in the bottom area. Rates are associated with higher area deprivation. However, rates were not standardised by age and it is likely that different results might have arisen if age standardisation had been done.
SPOZATI	1996	São Paulo	All ages	96 areas	Homicide rates, Potential years of life lost, 0-4 and 15-24 year old group mortality rates showed a correlation with socio-environment patterns. However, because the aim of the study was to build maps of the social exclusion, the health indicators were not further explored.
DRUMMOND-JR.	1996	São Paulo	Adults (15-64 years)	56 areas	In 1991, There were 3096 "exceeding deaths" for males and 2024 for females. Seventy per cent (males) and 65% (females) of the all-exceeding deaths occurred in the most deprived areas. The main causes were homicides and cerebrovascular diseases (males), IHD, and cerebrovascular diseases (females).
PBH	1996a	Belo Horizonte	All ages	81 areas	Maps of quality of life were produced using 39 variables. Infant morality and homicide data were among the variables. The excessive number of correlated variables produced results with low degree of discrimination. The highest score was only twice the lowest score.
SOUZA ET AL	1997	Rio de Janeiro	10-19 years at death	8 areas	Areas with high proportion of the population living in favelas presented high rates of homicides. Findings related to MVTA are inverse.
SZWARCWALD AND CASTILHO	1998	Rio de Janeiro	10-39 years at death	66 municipalities	The rise of homicides due to firearms has happened in the whole of the Rio State contradicting the claim that violence concentrates in extreme poor areas. Intra-urban variation was not analysed.
COSTA AND NATAL	1998	S. José do Rio Preto	All ages	264 Census tracts	Spatial distribution of 1,206 cases during Dengue (serum type I) epidemics is studied. The geographical taxonomy is poorly explained. The study only describes the incidence in each category (three). Incidence is inversely associated with the socio-economic status of the areas. However, the univariate analysis presented no significant result.
LIMA AND XIMENES	1998	Recife	All ages	94 neighbourhood	The spatial distribution of 1,181 deaths (due to external causes) is analysed. The neighbourhoods are classified according to the income of the head of the family. No significant correlation was found. However, in

					Brazil, neighbourhood (*bairro*) is not recommended for ecological comparisons because its socio-economic heterogeneity. In the study, the *bairros* present similar age structure, suggesting that population, with different demographic patterns, are mixed up producing a false demographic homogeneity.
BARATA ET AL	1998	S. Paulo	All ages	96 districts stratified in 5 Regions	Age and sex adjusted homicides rates are inversely related to living condition status. Living condition status of the regions was assessed through a composite index (income of the head of the family, illiteracy, rooms per household and overcrowding).
SZWARCWALD ET AL	1999	Rio de Janeiro	Infants, Adults (15-29 years), All ages	24 Administrat. Regions	The association between health indicator and socio-economic indicators are studied. The health indicators considered are infant mortality, SMRs (All causes), life expectancy at birth and homicide rate (15-29 years at death). The socio-economic indicators considered are: Gini index, Robin Hood index, top 10%/botton 40% average income ratio. Correlation between the socio-economic indexes and the health indicators were found. Further more homicides seems to be associated with density of favelas residents.
SILVA AND PAIM	1999	Salvador	All ages	66 areas	The distribution of SMRs, age specific mortality rates proportional infant mortality rate and proportional mortality ratio according to socio-economic strata. The strata are classified according to income or education of the head of the family or proportion of household in favelas.

Some methodological problems can be perceived through analysis of methods used in the studies mentioned above. Just recently some studies have covered adult populations and cause-specific mortality. The areas represent large and heterogeneous populations. The majority of studies concentrate on main cities such as São Paulo and Rio. Descriptive statistical techniques prevail. The studies basically compare the standardised mortality rates (SMR) of different areas classified according to income or composite indexes. From 1998 onwards, some regression methods have been tried but multivariate analysis have not been tested. Only one study deals with spatial auto-correlation. This study proposes to investigate the association of deaths due to infectious and external causes with socio-economic and environmental factors. The study took place in a middle size population city, using homogeneous geographical units. These issues will be further explored in the chapter on methodology.

2.6 Cause-specific mortality and urban inequality in health

Poorer urban areas experience a double burden of disease. Diseases associated with both the modern pattern of death and the old pattern of death seem to be highly present in low-income settlements (HARPHAM ET AL, 1988). This section will focus on two tracers of the double burden pattern: infectious and parasitic diseases, and injury and violence.

The attributes "old" and "modern", used to define epidemiological patterns, come from epidemiological transition theory. OMRAN (1971), who first presented the theory, suggested that mortality and disease shifts whereby infection and transmitted diseases (old or remaining diseases) patterns are progressively replaced by chronic and degenerative diseases and violence (modern diseases) patterns. Despite being constant in human civilisation, injury and violence are included in the modern set because they suggest a new pattern rather than the rebirth of an old ailment. In recent centuries, handguns and motor vehicles (20^{th} Century) have been introduced to human civilisation. Nowadays, they have become responsible for the majority of deaths due to injuries and violence in the world.

Preceding the double burden mortality are the expositions to both traditional (poor sanitation, indoor pollution) and modern risks (industrial pollutants, violence). This risk overlap has important implications for health profiles and affects urban slum areas where there are usually high levels of interaction on two different levels: socio-economic factors interact with environmental ones, and, at the environmental level, traditional risks interact with modern risks (SMITH AND LEE, 1993). Socio-economic factors produce and interact with environment factors shaping the epidemiological profiles.

Infectious diseases and external causes represent the paradox in the epidemiological transition of developing country cities. It is the crossroads where infectious diseases are still frequent while deaths due violence have had marked increase. The following sections will present the definition and aetiology, risk factors and trends in infectious diseases and external causes of death, focusing on Brazil and Belo Horizonte City.

2.6.1 Infectious diseases: definition and relevance

Definition and aetiology

This section focus on the literature review of the prevalent infectious and parasitic diseases that are associated with high mortality levels.

Infectious or communicable disease is an illness due to transmission of a specific infectious agent or its toxic products from an infected person, animal, or reservoir to a susceptible host, either directly or indirectly (LAST, 1988).

Infectious diseases involve three components: the agent, the transmission process, and the host. "The environment plays a critical role in the development of communicable diseases. General sanitation, temperature, air pollution and water quality are among factors that influence all stages in the chain of infection. In addition, socio-economic factors, such as population density, overcrowding and poverty, are of great importance" (BEAGLEHOLE ET AL, 1993, p.102).

Infectious diseases are mostly included in chapter I of the International Classification of Diseases, ninth revision (ICD-9th), under the title Infectious and Parasitic Diseases. Within Chapter I, the diseases are coded between 002-139. However, some infectious diseases can also be found among other ICD-9th chapters, such as pneumonia and influenza (480-487) in the chapter VIII.

In Europe and USA since October 1986, AIDS is coded as 042-044 in the Chapter I of ICD-9^{th} (CDC, 1987). However in Brazil, it is still coded as 279.1. Thereby, it is excluded from the Chapter I of ICD-9th. AIDS is not considered in this study because the links between physical environmental factors and the disease have not been established.

The infectious agents cover a broad number of micro and macroparasite species. They encompass bacteria, viruses, protozoa, and helminths. However in the large South-Eastern cities of Brazil a few diseases are responsible for the majority of the deaths.

In the large cities of the South-Eastern region of Brazil, diarrhoeal syndromes in children, pulmonary tuberculosis in older ages, and septicaemia are the important underlying causes of deaths due to bacteria (SABROZA ET AL, 1995). A large number of bacterial species are linked to diarrhoeal syndromes. The main bacteria related to deaths due to diarrhoea is Escherichia coli.

Mycobacterium tuberculosis is the etiological agent of tuberculosis. Symptoms, site, and extension of tuberculosis, vary greatly among the cases. As a consequence, the only and "obvious" classification allowed is: pulmonary, non-pulmonary, and widespread forms (GRANGE, 1988). The pulmonary form is associated with the airborne transmission of the disease, which seems to be responsible for all new infections (STYBLO, 1991, SNEIDER, 1994).

Pneumonia can be associated with many etiologic agents. However, environmental studies usually focus on those transmitted by close contact with infectious individuals. In this case, pneumococcus, Clamydia pneumoniae, and Mycoplasma pneumoniae are the common causes of community-acquired bacterial pneumonia. They are usually acute, being the most prevalent in both developed and developing countries (RODIER ET AL, 2000).

During the eighties, efforts to control poliomyelitis in Brazil have entirely succeeded (SABROZA ET AL, 1995). Thereby HIV and Hepatitis B virus have become the main viruses associated with deaths due to infectious diseases.

Trypanosoma cruzi, a protozoon, is the infectious agent of American trypanosomiasis or Chagas Disease. In Brazil, due to intensive and massive campaigns, which controlled 85% of Triatoma infestans[15] in the endemic areas, the triatomines have totally been banished from urban areas. However, carriers of the Chagas Disease from rural areas have moved to urban areas.

In the Brazilian South Eastern cities, the helminths play a small role in mortality. In Belo Horizonte, the most prevalent helminthiasis is Schistosoma mansoni[16].

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[15] In Brazil, *Triatoma infestans*, a domestic triatomine bug, has been the main vector of Chagas Disease until the eighties. *Panstrogylus megistus*, *Triatoma sordida*, *Triatoma brasiliensis*, and *Triatoma pseudomaculata* are also vectors in the infection process of Chagas Disease (DIAS, 1994).

[16] *Schistosoma mansoni* belongs to class Trematoda of the phylum Plathelmintes or flatworms. It is responsible for schistosomiasis or bilharziosis (BUTTERWORTH and THOMAS, 1996).

Classificatory systems have been proposed as a means to define the role of environmental factors either as sources or components in the infection. Some authors have proposed the classification of water related infections (WHITE ET AL, 1972, FEACHEM, 1977, CAIRNCROSS AND FEACHEM, 1993).

CAIRNCROSS ET AL (1996) recently proposed a broad classification based on transmission routes: The domestic domain, the area occupied by the household and peri-domestic spaces, and the public domain, which encompass schools, workplaces, hospitals, and roads and fields. This classification contributes in the comprehension of the transmission routes, therefore it can help the definition of preventive health measures.

Box 2-2 presents the physical environmental factors and related diseases in Belo Horizonte in 1994. The factors can be present at home, surrounding environment, school and the work place.

Box 2-1 Physical environmental factors and related infectious diseases in Belo Horizonte - 1994

Factors	**Diseases**
Poor Sanitation	Diarrhoeas, Intestinal worms, Hepatitis A and D, and Cholera
Overcrowding	Tuberculosis, Pneumonia, Intestinal Worms, Acute Respiratory Infections, and Leprosy
Contaminated drinking water	Diarrhoeas, Intestinal worms, Hepatitis A and D, and Cholera
Inadequately protected stored water	Dengue
Litter collection and disposal	Diarrhoeas, Intestinal worms, and Leptospirosis
Indoor air pollution	Acute respiratory infections
Ventilation	Acute respiratory infections, Tuberculosis, and Meningococcal meningitis
Hygienic practices	Diarrhoeas, Intestinal Worms, and Hepatitis A and D
Food	Diarrhoeas, Hepatitis A and D, and Typhoid fever
Open sewage	Diarrhoeas, Intestinal Worms, and Cholera
Water for recreational purposes (lakes, rivers etc.)	Schistosomiasis, Diarrhoeas, Hepatitis A and D, and Cholera

The occurrence of infectious diseases is associated with multiple agents and risk factors. For example, diarrhoea due to infectious agents is the predominant infectious disease and is also associated with diverse determinants.

Social risk factors might operate during the whole infectious process, i.e., from the transmission to healing or death. Social conditions interfere in the health status that precedes the infection and the access to treatment. In addition, the route of transmission of each infectious disease depends of a given environment, which is strongly influenced by the social factors.

Epidemiological investigations should analyse the links between socio-economic and environmental factors in an attempt to define the contribution of each factor on the mortality due to diarrhoea. This knowledge can inform the health policy makers to tackle the most lethal diseases among all remaining infectious diseases in urbanised areas.

Trends in mortality due to infectious diseases

The WHO (1999) estimated that infectious diseases are responsible for 25 % of overall death worldwide, in 1998. They are still the leading mortality cause among children and young adults, 63% of all causes among children at age 0-4 years and 48% among those at 0-44 years. Six diseases are responsible for 90% of deaths. These are in this order: acute respiratory infections (mainly pneumonia and influenza), AIDS, diarrhoeal diseases, tuberculosis, malaria and measles. In developed countries 99% of deaths of children occur due to pneumonia.

In 1990, lower respiratory infections and diarrhoeal diseases were the leading cause of death on the global burden of deaths[17] because they mainly reached children and young adults (MURRAY AND LOPEZ, 1996a). These authors predicted that the continuous fall of the mortality due to those diseases can produce a scenario in 2020 in which they would be

[17] In this work the authors estimated the burden of death through Years of Life Lost (YLLs). The formula and nomenclature of YLLs are fully expressed in MURRAY, C. and LOPEZ, A. (eds.) (1996a). *Global burden of disease and injuries series*, volume 1: Global Health Statistics. pp 64-66.

supplanted by ischaemic heart disease, MVTA, and cerebrovascular disease as the main contributors to the global burden of death.

Table 2-2, adapted from the work of MURRAY AND LOPEZ (1996b), compares the Latin American scenario of diarrhoeal diseases and lower respiratory infections with established market economy countries[18] and the whole world. The comparison between Latin America and the established economy countries allows evaluating the international gap in health, taking the latter group as a reference for the most favourable condition in health terms.

The children (0-4 years) of Latin America experience the higher levels of mortality than the established market economies, but the levels of mortality in Latin American and Caribbean countries are below the world level. Children from Latin America present diarrhoeal mortality rates 328 times higher than their counterparts in the established market economy countries. In relation to lower respiratory infections, Latin American and Caribbean children present a mortality rate 33 times higher than the established market economies.

Table 2-2 Mortality Rates of diarrhoeal diseases and lower respiratory infections in Established Market Economies, Latin America and the Caribbean, and the World, all ages and 0-4 years at death, per 100,000 Population – 1990

Regions/Diseases by age	Diarrhoeal diseases		Lower respiratory infections	
	all ages	0-4 years	all ages	0-4 years
Established Market Economies	0.3	0.7	34.1	5.3
Latin America and the Caribbean	34.5	229.4	40.1	174.5
World	55.9	393.1	82.6	408.4

Adapted from MURRAY, C. and LOPEZ, A. (eds.) (1996b). *Global burden of disease and injuries series*, volume 2: Global Health Statistics. Harvard School of Public Health/WHO/World Bank.

LEVINE AND LEVINE (1995) have argued that the impacts of infrastructure interventions and food availability on health can be reduced due to interference of social and economic factors. They focus on human ecology and behaviour related to diarrhoeas, but these factors are equally valid to lower respiratory infections in children. The authors enlist: living in deprived

[18] Industrial countries are usually considered as the established market economies such as USA, UK, JAPAN and New Zealand.

urban areas, decreased breast-feeding, sudden shifting in regional economic activity, and social and political instability.

In general, infectious diseases are declining as the cause of morbidity and mortality. However, some of them are in fact emerging and/or spreading. AIDS and tuberculosis (related to AIDS) are the most dramatic examples. The WHO (1999) has reported unexpected outbreaks of 33 emerging or re-emerging diseases during 1994-99 in the whole world. However, only a few diseases tend to remain at global level (CLIFF AND HAGGETT, 1998). Most of them will be restricted to developing countries where the combination of unfavourable socio-economic and environmental conditions, with a lack of efficient health interventions can allow them to have a prolonged relationship with the human populations.

The Brazilian scenario

Brazil experienced a sharp decline of mortality due to infectious diseases in this century. However, high levels of infectious disease are still present due to social and regional inequalities among the distribution of wealth resources (BARRETO AND CARMO, 1995). According to DATASUS (1999), an agency of the Brazilian Ministry of Health, infectious disease was responsible for 8% of overall deaths in Brazil, in 1986. Ten years later, the contribution of infectious diseases had been reduced to 6.8%. However, in the state of Acre in the far Amazon region (North), infectious diseases claimed 12.6% of all deaths in 1996. In addition, some infectious diseases have recently expanded in Brazil, such as leishmaniasis and tuberculosis (PAHO, 1998).

Some controlled diseases, such Chagas Disease, are still important items on the Brazilian health agenda. In 1992, DIAS (1994) estimated that 5 million Brazilian people remained infected by the infectious agent of Chagas disease, and 65% of the all infected population has moved to urban areas. The socio-demographic profile of the Chagas disease urban carriers is characterised by low educational and professional status (SILVA ET AL, 1995).

POSSAS (1989) has explained the permanence of high levels of infectious diseases in some regions as the result of the socio-economic structural heterogeneity, and this means a polarised regional scenario within Brazil. Some regions of the country (North and North-Eastern) have a high prevalence of infectious diseases, while others (South and South-Eastern) present prevalence rates close to those as developed countries.

In relation to the 80s, in Brazil, BARRETO ET AL (1996) state that despite the decline of the mortality due to infectious diseases, specially diarrhoeas, the levels of hospitalisations of these diseases were kept stable. Hence, they concluded that the case fatality rate had decreased but not the morbidity. According to PAHO (1998), in 1995 and 1996, 25% of all hospitalisations in children under 1 year was due to diarrhoea. PAHO (1998) also report that from January to October 1996, 160 091 hospitalisations due to diarrhoea occurred in Brazil. They consumed 12.5% (around 20 millions US$) of the public health expenditure related to children at that age.

In the main cities of the developed South Eastern region, the infectious disease mortality is still an important cause of mortality, but few diseases concentrate most of the cases. In Belo Horizonte city for example, in 1994, the main causes related to parasitic and infectious agents were: septicaemia, ill-defined intestinal infections, Chagas Disease, and tuberculosis. These four underlying causes were responsible for 92.5% of all deaths due to infectious and parasitic diseases for all ages (DATASUS, 1999).

2.6.2 External causes of death

Definition

External Causes of Death are broadly classified as: unintentional accidents, homicide, suicide and injury resulting in legal intervention or undetermined intention (ANZOLA-PÉREZ AND BANGDIWALA, 1996). Motor vehicle traffic accidents (MVTA) are included in the former category. Among the deaths classified routinely as unintentional accidents there are probably cases of suicide and homicide but it is not possible to identify them in practical terms.

Nowadays, the concept of injury is preferred to that of accident because the word 'accident' suggests that the event occurred by chance. In fact, "injuries occur with definable patterns which help to identify risk factors and thereby imply strategies for prevention" (STANSFIELD ET AL, 1993, p. 629). The term injury comes from the Latin "incuria", meaning careless. This semantic discussion leads to a important aspect of external cause of death prevention: are their determinants related to accidental factors or to negligence and inadequacy?

Injury refers to human damage due to acute exposure to mechanical, electrical, thermal or chemical factors, or the lack of essential conditions, e.g. oxygen, heat (STANSFIELD ET AL, 1993). The exposure to injury factors is sudden and the damage is immediately perceived (BAKER ET AL, 1987). The outcome is commonly associated with injury by physical and chemical means.

Violence can be defined in a sociological, psychological or philosophical perspective. However, epidemiological studies commonly focus on mortality or morbidity due to physical violence by a presumed intentional or unintentional act. It can be caused by others or be self-inflicted. In fact the core of epistemiology of contemporary epidemiological studies of violence has come from the infectious disease epidemiology (ROBERTSON, 1992). As the infectious disease studies, most of the violence studies have focused on proximate determinants (such as type of weapon, speed, time). The social determinants still demand a better understanding, in special in countries like Brazil that are facing a dramatic rise in mortality due to external causes.

Injury resulting from legal intervention or undetermined intention can also allow for misclassification. Some of the cases could be produced by intentional and unnecessary acts (ANZOLA-PÉREZ AND BANGDIWALA, 1996), but these circumstances cannot be assessed in routine investigations.

External cause of deaths are included in the Supplementary Classification of External Causes of Injury and Poisoning (ICD-9th) and grouped into the following categories:

- Transport accidents (E800-E848). Motor Vehicle Traffic Accidents encompass E810-E819
- Other unintentional accidents (E850-E949), e.g. domestic accidents

- Suicide (E950-E959)
- Homicide (E960-E969)
- Injury due to legal intervention (E970-E978)
- Injury undermined whether accidentally or purposely inflicted (E980-E989)

Risk factors for external causes of death

External causes of death present specific risk factor profiles among urban populations. The road traffic accidents are associated with demographic characteristics, drug consumption, factors related to vehicles, and the lack of preventive measures.

Many authors prefer to identify the specific agents of the external cause of deaths in terms of various forms of energy: mechanical energy, heat, electricity, chemicals, and ionising radiation (HADDON, 1980). They attempt to apply the principles of infectious disease epidemiology to violence and injury studies (ROBERTSON, 1992). Thereby, vehicles, bullets, high-voltage power lines would be the *necessary, specific agents of injury*[19] (HADDON, 1980).

In developing countries the incidence of MVTA is higher in males, and in adults of over 25 years old. In developed countries males are also at higher risk, but the age group of 15-24 is responsible for the highest rates. This inverse tendency seems to be associated with the age of acquisition of the motor vehicles (KJELLSTROM ET AL, 1992).

Drugs and alcohol consumption play an important role in the occurrence of transport accidents (STANSFIELD ET AL, 1993). The rise in the number of vehicles and the type of vehicles (e.g. motorcycles) has been correlated with the rise in mortality due to transport accidents (KJELLSTROM ET AL, 1992). The lack of specific legislation and educational preventive measures are also associated with high levels of mortality due to MVTA (ROBERTSON, 1984).

[19] " The recognition of such agents, especially mechanical energy, as necessary and specific causes of various kinds of injuries simultaneously pointed me toward the means of their transmission, again in close analogy to the concepts and substance of classic epidemiology" (HADDON, 1980, p. 412).

ZWI (1993) enlisted the factors associated with MVTA in developing countries into:

- Insufficient laws and public transport policy
- Environmental conditions: overloading of vehicles, urban overcrowding, heavy vehicles using the same roads at the same time as slighter vehicles, inadequate lighting, poor road signing and poor road conditions (e.g. narrow bridges, absence of pavement)
- Factors related to vehicles: inadequate maintenance of vehicles, lack of use of safety measures, use of less protected vehicles (e.g. open vehicles, motorcycles)
- Factors related to drivers: speeding and reckless overtaking, insufficient training and not in possession of driving licence, alcohol and drug consumption, exhaustion
- Factors related to pedestrians: poor education, poor visibility, alcohol and drug consumption, incorrect evaluation of oncoming vehicles speed

In relation to homicide, The NATIONAL COMMITTEE FOR INJURY PREVENTION AND CONTROL (1989), from USA, has focused on the following risks: socio-economic status, alcohol and drug consumption. Culture and attitudes are considered in the same study as important factors in the homicide determination, such as children hearing violent practices, racism, and homophobia. Places of residence and ethnicity also presented a correlation with the rates of homicides (KJELLSTROM ET AL, 1992).

In Denmark, HEDEBOE ET AL (1985) found a strong association between interpersonal violence and time. He concluded that assaults and violence were more frequent at night and during the weekends in 1982.

In United States, alcohol abuse, depression and anxiety disorder, and aggressive behaviour have been reported as consistent risk factors associated with suicide (SHAFFER, 1993). In Switzerland, depressive symptoms have been considered the most frequent factor related to suicides and to serious attempts of suicide (MICHEL, 1987). In England and Wales, "the unskilled lowest social class male group has more than eight times the rate of attempted suicide as the professional highest social class male group" (WHO, 1982, p. 26). The availability of the means to commit suicide, especially handguns in North American urban areas, has found to be an important factor in suicides committed by youngsters and children (BRENT ET AL, 1993).

KAWACHI ET AL (1999) have tried to study the violence as an broad indicator of the collective well being. In USA, they found evidence of the association between violence and relative deprivation (income inequality) and the lack of social cohesion[20]. They found that the areas with high homicide rates also present high mortality rates from all causes of death, suggesting that crime and community health status share the same determinants.

The emergence of the illegal drug market has dramatically increased the violence rates in Latin American Countries (HABITAT, 1996). However, the drug market data is unavailable for epidemiological study purposes.

Trends in mortality due to external causes

Since early 1970s, industrial countries have shown a decline in the trends of mortality from external causes. This is due to the dramatic reduction of deaths by MVTA (LOPEZ, 1993). However, suicide rates are still increasing among the established market economies, though at levels those do not compensate the impact of the fall in MVTA in the group of injury and violence. In post-communist societies, mortality due to external causes has increased.

The United States has been an exception among the established market economies. The USA exhibits a specific profile of violence and injuries among the established market economies countries. In 1978, homicide rates were 9,4 deaths per 100,000 Americans and suicide rates were about 12,5 per 100,000 population (CHESNAIS, 1985). In 1985, MVTA were responsible for 19.4 deaths per 100,000 Americans (ROBERTSON, 1992). Suicides and MTVA rates were comparable to European patterns, while homicide rates were similar to some South American countries.

Inside the North American society, ethnic and social groups face different probabilities of dying because of violent events and/or injury. Using aggregated data from 1980 to 1986, BAKER ET AL (1992) found the following MTVA death rates per 100,000 population: whites

[20] The degree of cohesiveness in social relations among citizens is measured by social capital and collective efficacy (KAWACHI ET AL, 1999). Social capital relates to "features of social organization, such as networks, norms of reciprocity, and trust in others, that facilitate co-operation between citizens for mutual benefits" (p. 729). Collective efficacy relates to the combination of "a neighbourhood's level of social cohesion with its extent of informal social control" (p. 729).

20.42, blacks 16.88, and native Americans[21] 41,97. While for suicide the whites exhibited 13.23, blacks 6.09, and native Americans 13.12. Rates for homicide were: 5,91 for whites, 32.36 for blacks, and 14.01 for natives. White Americans experienced approximately same level rates for suicide and MVTA than those encountered in European countries. MVTA death in Native Americans and homicide rates in black Americans were exceedingly high when compared to those experienced by Europeans.

In the aftermath of the soviet era, some Eastern European countries have experienced a dramatic increase in homicide and suicide. In Russia for example, LEON ET AL (1997) observed that the homicide rate (for both sexes) was fourfold higher in 1994 than 1987. In the same period, suicide rates doubled. The impact of the social and economic transition, aggravated by the lack of social cohesion, seems to play a greater role in the epidemics of homicide and suicide (WALBERG ET AL, 1998). In 1994, seven out of eight countries with the highest prevalence of external cause mortality were former Soviet republics[22] (BARSS ET AL, 1998).

In some developing countries mortality rates for homicide and MVTA seem to be increasing. Between 1968 and 1983, in Africa and Asia, mortality due to MVTA increased by over 150% (SÖDERLUND AND ZWI, 1995).

In the Americas the risk of dying due to external causes vary dramatically among the countries. In the late 1980s, while North American and Canadians (1989) presented respectively death rates of 9 and 2 per 100,000, Colombians (1989) and Brazilians (1988) presented respectively death rates of 73 and 17 per 100,000 (CEDEC, 1996).

Table 2-3, from the work of MURRAY AND LOPEZ (1996b), compares the Latin American scenario of violence and injuries with established market economy countries. The male population experienced the highest differences. Males from Latin America and Caribbean present homicide rates 6.9 times higher than their counterparts in the established market economy countries. In relation to MTVA for males and for the overall population, Latin America and Caribbean rates are 2.5 times higher than the established market economy

[21] Native Americans encompass the Amerindians, the Eskimos, and the Aleuts.
[22] In 1994, the countries with highest external causes were by order: Russian Federation, Latvia, Estonia, Lithuania, Kazakhstan, Colombia, Belarus, and Ukraine. Among the 20 countries with the highest rates there were 14 former Soviet or former Eastern-European communist countries (BARSS ET AL, 1998).

countries. An inverse trend is presented for suicide, with Latin American and Caribbean males present mortality rates 2.9 times lower than the other mentioned countries.

Table 2-3 Mortality Rates of MVTA, Homicide, and Suicide in Established Market Economies, Latin America and the Caribbean, and the World, by Sex, per 100,000 Population – 1990

Regions/Diseases by Sex	MVTA			Homicide			Suicide		
	M	F	Total	M	F	Total	M	F	Total
Established Market Economies	24.1	9.2	16.5	5.8	2.9	3.8	20.7	7.7	14.0
Latin America and the Caribbean	36.2	13.0	24.6	40.0	5.8	22.9	7.1	3.0	5.1
World	27.5	10.3	19.0	16.5	4.7	10.7	17.2	12.6	14.9

Source: MURRAY, C. AND LOPEZ, A. (eds.) (1996b). *Global burden of disease and injuries series*, volume 2: Global Health Statistics. Boston, Harvard School of Public Health/WHO/World Bank.

Latin America is the leading region in the world for deaths due to external causes, especially for homicides and MVTA. This high levels in violence coincides with the permanence of high rates of mortality due to diarrhoeal diseases and lower respiratory infections, as it was shown in table 2-2. This disease trends overlap produces a complex scenario, demanding health policies in both directions: toward old and modern diseases.

Latin America has experienced a general decrease in mortality rates due to injury and violence. However, specific groups have faced increasing rates of mortality related to MVTA or violent acts. Between 1968 and 1987, Cuban women and Colombian men have been affected, respectively, in rising levels of suicide and homicide (ANZOLA-PÉREZ AND BANGDIWALA, 1996). In Colombia, 35.3% of all the male deaths were related to injuries and violence in 1990 (RUIZ AND RINCÓN, 1996).

According to BULATAO (1993), injuries and accidents were responsible for 7.5% of all deaths in Latin America and Caribbean in 1985. In the same year, these countries have presented specific mortality rates of 90 (male) and 29 (female) per 100,000 population.

In Latin America[23], the contribution of external causes of death to all-cause mortality has increased. The male population is disproportionately affected (ANZOLA-PEREZ AND

[23] The differences for Latin countries to the traditional industrial countries are better observed through age standardised death rates. In 1985, the former presented 64 per 100,000 while the latter presented 51 per 100,000 population (BULATAO, 1993).

BANGDIWALA, 1996). The availability of vehicles in emergent economies of developing countries has produced progressively higher mortality rates due by MVTA. "Middle-income countries appear to have on average, the largest road-traffic mortality burden" (SÖDERLUND AND ZWI, 1995, p.480). This seems to be the Brazilian scenario.

YUNES AND RAJS (1994) classified Latin America countries according to the trends of injury and violence between 1976 to 1990. Colombia, Cuba, Chile, Mexico and Surinam presented mortality rates due to external causes as between 65 to 125 per 100,000 population. Brazil, Venezuela and Puerto Rico were considered to be at an intermediate level, with a mortality rate of 51 to 74 per 100,000 population due to external causes. Argentina, Costa Rica and Uruguay presented mortality rates under 65 per 100,000 population.

The Brazilian scenario

External causes of death have increased dramatically as a proportion of the total mortality in Brazil. Proportional mortality due to external causes has increased from 2.6% in 1930 (ARAÚJO, 1992) to 15.3% in 1989 (SOUZA AND MINAYO, 1995).

YUNES AND RAJS (1994) have found upward trends for all age groups between 1979 and 1986. In 1987, the mortality rates due to external causes indicate 70 per 100,000 population (MELLO JORGE, 1994). In 1997, the external cause mortality rate reached 74.8 per 100,000.

According to DATASUS (1999), violence and injuries are the second leading cause of death among the Brazilian population. In 1997, external causes were responsible for 18.8% (male) and 5.3% (female) of all deaths in Brazil. External cause of deaths was the leading category among the 5-49 age groups. MVTA and homicides were the main contributors to the burden of external causes of deaths. In 1997, at least 40,472 persons died due to homicides and 35,736 died due to MVTA.

In 1997, death rates due to MVTA were 22.4 per 100,000. In 1997, homicide exhibited a mortality rate equal to 25.4. Suicide has been a rare underlying cause of death in Brazil (1988), accounting for just 4.3 deaths per 100,000 population. However, deaths due to homicides and suicide are underestimated because 9,113 deaths could not be classified intentional neither unintentional. Further more, only 24 deaths were classified as a result of legal intervention, evidencing and underreported violence in Brazil (DATASUS, 1999).

Metropolitan areas in the Southeaster region presented very high rates for homicide and MVTA (DATASUS, 1999). In 1997, the metropolitan regions of Rio, São Paulo, and Belo Horizonte, presented respectively the following mortality rates due to external cause of deaths per 100,000 population: 116.6, 108.8, and 76.2. Rio and São Paulo showed upward trends during the eighties. Belo Horizonte seemed to present rather constant rates in the same decade. Between 1980 and 1997, homicides have played a main role in the rising trends of external cause of deaths in Rio and São Paulo. In 1997, homicide rates in the main Southeaster Brazilian metropolitan region were: 59.1 (Rio), 54.5 (São Paulo) and 18.2 (Belo Horizonte).

Since the late 1980s, Rio de Janeiro and São Paulo have presented similar MVTA rates. In 1997, Rio, and São Paulo, presented respectively the mortality rates due to MVTA per 100,000 population: 24.0 and 23.9. Among the Brazilian metropolitan regions, Belo Horizonte has presented the highest MVTA mortality rate. In 1997, Belo Horizonte presented MVTA mortality rate equals to 26,8 per 100,000 (DATASUS, 1999).

In Rio City, MVTA involving collision with pedestrians was responsible for 2/3 of the deaths of the whole MVTA in 1990 (KLEIN, 1994). In São Paulo City (1980) the same cause is related to 60% of the whole MTVA (MELLO JORGE, 1982). However, MELLO JORGE AND LATORRE (1994) observed for Rio that 20% of the deaths related to MTVA were classified as MTVA of unspecified nature. In Belo Horizonte and Contagem, in 1995, 49.1% of the deaths was due to collision with pedestrians (LADEIRA, 1995)

2.7 Conclusions

Urbanisation in the world is increasing rapidly, especially in developing countries. When compared to world rates, Latin American countries usually present lower levels of mortality due to infectious diseases and external causes. However, as Brazilian studies have shown, health and demographic indicators vary between and within the cities, suggesting that the gains of urbanisation have not being equally distributed among all settlers. Socio-economic differences and uneven health patterns have been part of the urban scenario in big cities in both Western and Eastern countries. Intra-urban differentials are a key problem.

Socio-economic, demographic and environmental factors are associated with intra-urban health inequality. Some epidemiological studies have tried to reveal the social determinants of health, to understand the changing health profiles of cities, to identify the most vulnerable groups, and to identify and measure the contribution of the risk factors associated with urban health problems.

More recently, there were important attempts to build up frameworks integrating macro-determinants with biological determinants of health. However, many aspects are unclear, demanding more evidence that encompass different societies and contexts.

The studies from Latin American countries are scarce. In Brazil for example, they have focused on infant mortality (and recently on violence) and on primary cities, using usually descriptive techniques. Disaggregated data studies carried out in São Paulo, Rio de Janeiro and in Salvador have revealed inequalities in mortality patterns within the cities.

This work intends to contribute to the epidemiological debate through studying health inequalities in a middle-size population city (Belo Horizonte) in a developing country (Brazil). In this study, both socio-economic and physical environmental factors will be analysed through descriptive and analytical techniques. These aspects will be properly discussed in the following chapters. Chapter 3 describes the hypothesis and objectives of this research and chapter 4 describes the methods used in this investigation.

Chapter 3 – Hypothesis, aims and objectives

3.1 Hypothesis

1. In developing countries, medium size cities, which are in an advanced stage of the epidemiological transition, socio-economic and environmental factors may have a high influence on the mortality variation, and this is more pronounced for some specific causes: infectious and parasitic diseases, and external causes of death.

2. Mortality from infectious diseases and from injury and violence is associated with an uneven distribution of the urban facilities and socio-economic and environmental standards.

3. Mapping and analysing the mortality variation within the city can suggest health policy interventions, through the definition of preference areas and groups, and also recommending specific measures for the control of diseases.

3.2 Aim and objectives

3.2.1 Aim

1. To investigate the relationship of socio-economic and physical environmental variables to mortality patterns within the City of Belo Horizonte (Brazil)

3.2.2 Objectives

1. To develop a set of socio-economic and environmental indicators from available data in Belo Horizonte.
2. To quantify the relationship between the socio-economic and environmental indicators and the mortality due to infections and parasitic diseases, and external causes of death.
3. To identify the most vulnerable health groups in relation to infectious diseases and external causes of death.
4. To interpret those relationships in light of available demographic and epidemiological research carried out in Belo Horizonte and Brazilian urban areas.
5. To discuss the implications of these results on models of the epidemiological transition and social exclusion in Brazil, in general, and in Belo Horizonte in particular.
6. To suggest health and urban policy recommendations flowing from these findings.

Chapter 4 - Methodology

4.1 Introduction

This chapter is divided into two parts. The first part is related to the study of site characteristics, explaining why Belo Horizonte was chosen, and describing its socio-demographic characteristics. The second part explores possibilities and limitations in the use of the chosen geographic units, reference population and mortality data, and analysis strategy.

4.2 Choice of city

As shown in the review chapter, intra-urban inequalities in heath have seldom been studied in secondary cities in Brazil. The main limitation is the absence of a comprehensive address database for mortality and morbidity studies. Only recently, have the cities from South and Southeastern regions started to build up information systems enabling studies to be undertaken.

Belo Horizonte was chosen for technical and pragmatic reasons. Belo Horizonte is a rich and unequal Brazilian city, being the third wealthiest Brazilian city, in aggregate economic terms. The socio-economic contrasts are marked in geographic terms. Wealthy areas are clearly separate from the poor areas (Figure 4-1). Belo Horizonte also has a middle-size population.

separate from the poor areas (Figure 4-1). Belo Horizonte also has a middle-size population. These characteristics provide a suitable environment for the study of intra-urban inequality in a secondary city of a developing country.

The Belo Horizonte municipality has the most comprehensive geographical information database related to one Brazilian city. The data processing agency of Belo Horizonte (PRODABEL) is responsible for collecting and storing the information about the city for administrative purposes. The Geographic Information System (GIS) database of PRODABEL (Data Processing Company of Belo Horizonte Municipality) has 5 millions vector objects and 1,500 raster maps[1], encompassing data related to buildings, roads, parks, urban equipment etc.

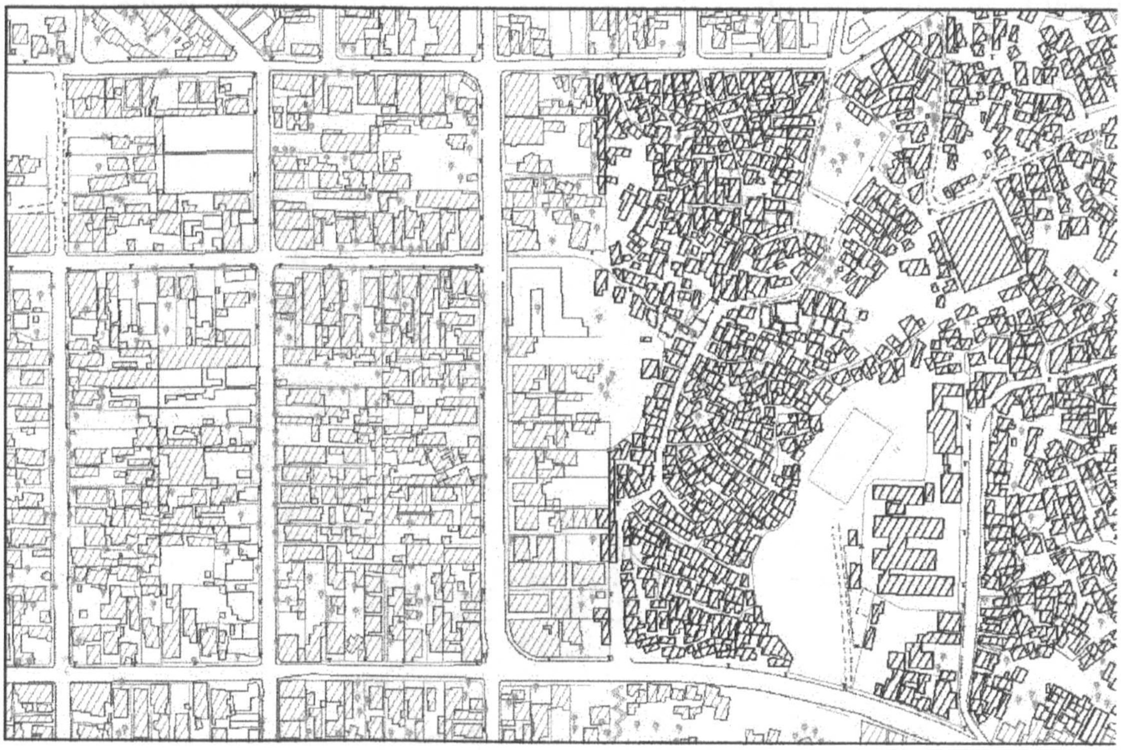

Figure 4-1 Aerial photo (digital format) of part of *favela* Prado Lopes and contiguous area, Belo Horizonte, 1989 (PRODABEL archives)

[1] Vector and raster relate to forms of computer representation of geographical data. Vector representation presents data through the three main geographical entities, points, lines, and areas. Raster or grid-cell representation presents data using a set of cells located by geographical co-ordinates (BURROUGH, 1986).

In PRODABEL, the author had been a senior analyst in population studies and GIS during 1993-95. The author is still a PRODABEL adviser in demographics and GIS applied to health studies. This relationship has proved useful for the development of the research. Data collection and data processing for this research was done with the full support of PRODABEL and the Health Department of Belo Horizonte.

4.2.1 Historical aspects

Belo Horizonte was founded in 1897 as the capital of the State of Minas Gerais[25] (Figure 4-2). The new capital was placed in the centre of the State (Map 4-3), in a geological depression called Belo Horizonte, protected by Serra do Curral [a chain of mountains]. Along this region there are two river networks: Arrudas and Onças. Both are offshoots of the River of Velhas.

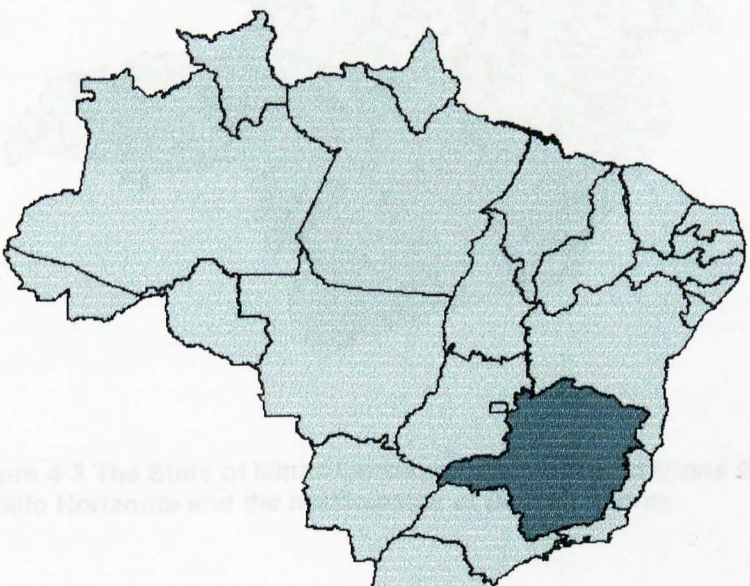

Figure 4-2 Brazil, Federal States and the State of Minas Gerais

[25] Brazil is a Federate Republic with 26 States and a District Capital.

According to the last Brazilian Special Population Census (1996), Belo Horizonte City has a population of 2,091,371 people, in an area of over 335 square kilometres. It has the fourth largest population in the country. The city of Belo Horizonte has rapidly changed its economic and demographic characteristics in the last 30 years.

In the first decade of this century the city of Belo Horizonte (BH) was already the second industrial textile centre of the state, and influenced the growth of the nearest industrial poles in the region that was to become its metropolitan area. Gradually, the industrial enterprises shifted to other cities within the metropolitan area (Figure 4-3).

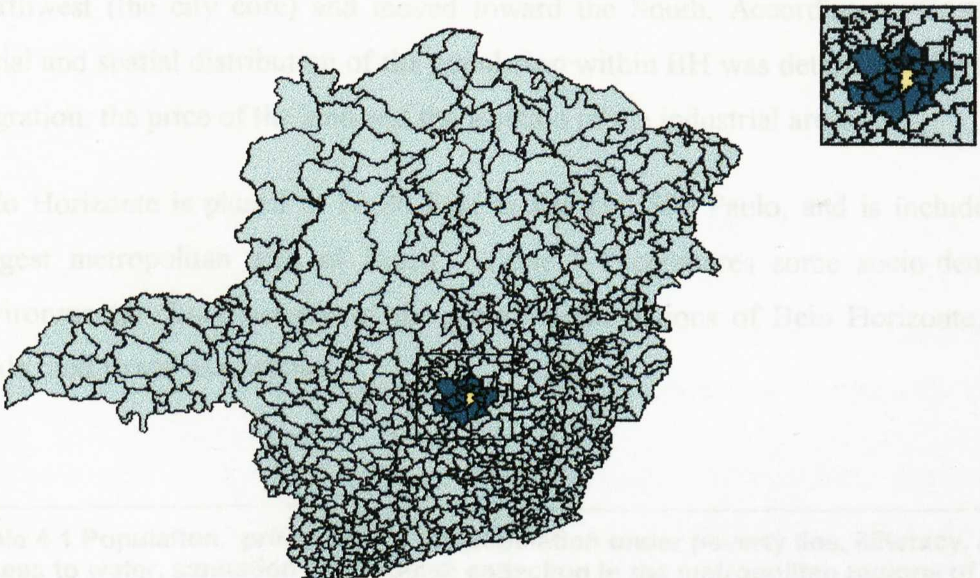

Figure 4-3 The State of Minas Gerais, municipalities of Minas Gerais, the Metropolitan Region of Belo Horizonte and the municipality of Belo Horizonte

Presently, the wealth of the city of BH is based more on a service economy than on manufacturing industries. In 1996, it had four big malls with an average of 180 shops each. Also it is a very important educational centre with three universities and five independent colleges. The city also has an important structure of health services, which include eight state hospitals, a charitable hospital and a large group of hospitals and clinics in the private sector.

In terms of distribution of the urban services, the city presents a peculiar pattern. Some areas have been subjected to gentrification. These "renewed" areas are hosting populations with higher education and income, without yet offering proper access to water, sanitation and litter collection. In addition, some prosperous areas are located in the highest part of the city, being very expensive to extend the urban services to these areas (such as water and sewage).

4.2.2 Socio-economic and environmental characteristics.

Historically the population settlement in Belo Horizonte originated in the South-centre and Northwest (the city core) and moved toward the South. According to COSTA (1994), the social and spatial distribution of the population within BH was determined by the rural-urban migration, the price of the land and the location of the industrial areas.

Belo Horizonte is placed in South East as Rio and São Paulo, and is included in the third biggest metropolitan area of Brasil. Table 4-1 compares some socio-demographic and environmental characteristics of the metropolitan regions of Belo Horizonte, Rio and São Paulo, and Brazil as a whole.

Table 4-1 Population, proportion of the population under poverty line, illiteracy, and lack of access to water, sanitation and rubbish collection in the metropolitan regions of Rio, São Paulo and Belo Horizonte, and Brazil - 1996

				Lack of access to urban facilities (%)		
Metropolitan Region	Population (million)	Pop. under poverty line[1] (%)	Illiteracy[2] (%)	Water	Sanitation	Rubbish collection
Rio	10.2	11.8	4.6	12.0	17.2	14.2
São Paulo	16.6	7.8	6.0	8.4	14.3	0.16
Belo Horizonte	4.8	16.2	6.4	8.4	22.6	17.7
Brazil	157.1	27.2	14.7	14.5	41.81	15.5

Source: DATASUS (1999)

[1] Earning inferior to ½ minimum wage, approximately £ 23.00 at March 1999 prices
[2] Illiterate population with 15 years old and over

In Belo Horizonte, the proportion of the illiterate population is lower than the national average, reflecting the improvement of the access to primary schools. The remaining illiterate population is basically the aged population and migrants from the countryside. In comparison to other metropolitan regions, São Paulo presents far better urban facilities than the Brazilian average. Rio and Belo Horizonte present deficient rubbish collection coverage. Sanitation coverage in Belo Horizonte and access to water in Rio are still insufficient. These problems seemed to be related to the combination of complex topography and social use of the urban space. In both cities, the poor have occupied the hills. The favelas, as they are named, are still fighting for access to basic urban facilities.

4.3 Study design

An ecological m*ultiple-group comparison study* was carried out in the City of Belo Horizonte. The study analysed the correlation between mortality rates and socio-economic and environmental factors within 75 geographical areas. The data was collected from specific data sources, and was matched through geographic information system (GIS) techniques.

The ecological analysis focused on the association between both socio-economic and physical environmental variables, and death due to infectious diseases, and injuries and violence.

In this second part of this section, the study design, the geographical units, the data sources, and the analytical strategy are described. The section starts by reviewing the meaning of ecological studies, and the possibilities and the limits of this method.

4.3.1 Justification for the choice of ecological studies

Epidemiologists divide epidemiological methods into two main groups: descriptive studies and analytical studies. The former group is supposed to describe, generically, the distribution of disease according to the following variables: person, place, and time. Analytical studies aim to study causal relationships between both exposure and attribute, and the risk of diseases.

HENNEKENS AND BURING (1987) considers two kinds of descriptive studies: individual and population studies. The former encompass case reports, case series and cross sectional surveys. The latter are identified as correlational studies, which is also nominated as ecological correlation (LILIENFELD AND STOLLEY, 1994) or ecological studies (GORDIS, 1996).

Analytical studies are classified in observational and intervention studies. Case-control and cohort studies belong to the former group, and clinical trials belong to the latter one.

This study will focus on the methods of the study of group characteristics, adopting the terminology of ecological study. Ecological studies are applied to the study of the association between an exposure or characteristics of a given group, and the risk of disease among them (GORDIS, 1996). Ecological studies consider the group as the study unit, while the analytical ones are based on the study of individual characteristics.

MORGENSTERN (1982) identified two major aims in ecological studies: "1) to generate or test etiologic hypotheses, i.e., to explain disease occurrence and 2) to evaluate the effectiveness of population intervention" (p.1336). The former assertion is controversial because ecological studies generate hypotheses but cannot easily test them.

ENGLISH (1994) has considered ecological studies as "a first step" in identifying an association between outcome and environmental variables. Ecological studies must be restricted to the initial "steps" for studying the aetiology of disease, because the findings are frequently unreliable indicators of a causal relationship (COMSTOCK, 1988). In ecological studies, causal inference is based on measurement of the risk at group level, and this may not represent the risk at individual level. This is the major problem in ecological studies, and is known as the ecological fallacy[26].

However a majority of the epidemiological community has accepted that ecological studies are very useful for public health because they are cheaper and faster than analytical ones

[26] Ecological fallacy encompasses two types of bias: aggregation bias and specification bias. The former is related to bias due to grouping the individuals and the latter is a consequence of an inference error in failing to distinguish different levels of organisation (LAST, 1988).

(COMSTOCK, 1988). They can also explore the association between many socio-environmental factors and diseases. Ecological studies can be important in generating an epidemiological hypothesis in rare or new diseases (ENGLISH, 1994). They also allow the assessment of the effect of collective actions on morbidity and mortality trends (MORGENSTERN, 1982).

MORGENSTERN (1982) classified ecological analysis into four types: exploratory study, multiple-group comparison study, time series study, and mixed study. The following section focus on multiple-group comparison study, which was used in this research, identifying the concepts, advantages and problems related to that.

4.3.2 Methodological problems in ecological studies: multiple-group comparison study type

Multiple-group comparison studies are related to the observation of the association between the average of exposure of a given factor and the disease rate among the observed groups. The differences are expected to be due to group variation in the average exposure level. The main uses of *multiple-group comparison studies* have been mapping and analysing the effects of socio-environmental variables and, principally, ambient exposures.

Mortality studies using *multiple-group comparison* approach are vulnerable to the same source of errors as any comparative study of mortality. Box 4-1 lists some main reasons for the differences in mortality rates in this type of study.

Multiple-group comparison studies deals with health outcome and exposure measurements at group level, both of which imply specific problems. Some studies have a vague case definition, e.g., heterogeneity in the definition of the disease, and the exposure is poorly characterised (ROTHMAN, 1990). Problems in routine data collection and the ecological fallacy are great disadvantages in ecological studies. However, there are several others, which are also listed in the Box 4-1.

Box 4-1 Outline of Determinants for Differences in Multiple-Group Comparison Studies of Mortality

1. Errors or artefact

A. Errors or artefact related to the numerator, which differ between groups:
1) Misclassification of the underlying cause of death
2) Underreporting deaths
3) Incorrect or lack of information of the place of residence of the subject

B. Error or artefact related to the denominator due to:
1) Inadequate population estimates
2) Small or sparsely populated area in rare diseases studies
3) Sampling error

C. Error or artefact related to the exposure variables due to:
1) Ecological fallacy
2) Heterogeneity in exposure
3) Measurement error (misclassification and not measuring)
4) Confounding
5) Non-comparable standardisation (available average may have non-comparable standardisation fashion)
6) Multicolinearity (some socio-economic and environmental variables tend to present higher correlation at group level than individual one, such as: education and race)
7) Overdispersion (unmeasured or unknown variables interfering in the outcome variation)

2. Real

A. Differences in age structure
B. Differences in survivorship (areas with female majority tend to have a population with a higher life span than those with male majority)
C. Differences in incidence of disease due to:
1) Genetic factors
2) Behavioural factors
3) Environmental factors
4) Socio-economic factors

Adapted from: LILIENFELD AND STOLLEY (1994), ENGLISH (1994), NURMINEN (1995), MORGENSTERN (1982), GREENLAND (1992), and CLAYTON AND HILLS (1996)

4.3.3 Minimising biases in the Belo Horizonte Study

This section describes the procedures undertaken in order to reduce the burden of errors in ecological studies, when focusing on the context of Belo Horizonte study.

The study assumed that the population within each geographical area is homogeneously exposed to the socio-economic and environmental variables. The average exposure was presented in tables 4-8 (in section 4.5.3). Six areas that presented population under 2,500 were excluded because they presented sparse or unusual populations, such as permanent inhabitants of a university campus, and builders of new areas. A remaining rural area was also excluded because of environmental data inconsistency[27]. Therefore, the selected area populations ranged from 2,584 to 70,872 (Annex 1).

In the multivariate analysis, all the variables that could be associated with the outcomes were included in the regression model (KLEINBAUN ET AL, 1998). A Poisson multiple regression model was used. An analysis of the influence of areas with unusual findings (outcome, exposure, and covariates) on the model was performed.

Data from 1993 was originally processed in an attempt to enlarge the number of cases and representativeness. However it could not be used because many problems related to: lack of death certificates for homicides, excess of ill-defined causes for deaths due to external causes, inconsistent for overall distribution of deaths across the geographical areas. In fact, 18 *planning unit*s, including some highly populated areas, presented very few cases, suggesting address misclassification. As a consequence only mortality data from 1994 was used in the analysis.

Two additional problems were considered: overdispersion and spatial autocorrelation (HILLS, 1996). The former refers to variability between the Observed/Expected death ratios (O/E ratio) that cannot be attributed to the Poisson variability alone. The latter relates to the fact that adjacent areas tend to present closer values for O/E ratios than expected by chance. The statistical procedures for dealing with those are explained in section 4.6.

Misclassification and effects of migration on exposure status were also investigated. Migration played a small role in the population dynamics of Belo Horizonte. The special population census[28] (1996) found only 5.3% of immigrants (in the previous 5 years) within the city. Among them 1.7% came from other areas within the Minas Gerais State, 4.5% came from other states of Brazil, and only 0.2% came from different countries. There was no important association between migration status and education of the head of the family. Unfortunately, in Brazil, data regarding intra-urban migration is not available. That remains

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[27] Six out of 81 PUs (including a *favela*) were excluded from the study because they were atypical areas, containing small populations in 1994. Barreiro Sul encompasses a mountain in the border South of the city with 1,488 population. Isidoro Sul, Pilar, Castelo, and Confisco presented populations of 1,622, 225, 2,190, and 2,218 respectively. UFMG delimits the campus of University of Minas Gerais, counting 28 permanent residents.

[28] The Brazilian population census has been taken regularly every 10 years since 1890. In 1966, occurred by the first time a special population census. In fact, it differs from the decenial census only by the number of questions present in questionnaire. The special population census collects fewer questions than the decennial population census.

as a probable source of bias because populations move internally experiencing different levels of exposure to the environmental variables.

Finally, unmeasured latency and induction periods of the causal process and obviously, the ecological fallacy remain as a limitation in this type of study.

4.4 Geographical Units

This section presents the methodology for defining the geographical units for this study. A key issue for the section focuses on matching the *planning units* (PU) with census tracts, considering elements of urban space such as thoroughfares and buildings. The *planning units* were originally developed by the municipality, using a different system from the census tract network developed by the Brazilian census bureau (IBGE). As consequence of the methodology that has arisen from this study, the municipality has redefined the borders of the PU and replaced alfanumeric codes by names. The new PU network can now be used as geographical units for geo-statistical analysis, since the two systems are now compatible.

4.4.1 Looking for adequate geographical units

In this research, the cartographic basis for the production of the spatial indicators should fulfil the criteria: compatibility with the geographic systems adopted by the municipality of Belo Horizonte, homogeneity in terms of exposure level, and compatibility between mortality, population and exposure data.

The government of the municipality of Belo Horizonte officially used four different geographical unit systems: Regional Administrative Areas, neighbourhoods, census tracts, and planning units (PU).

The nine Regional Administrative Areas were not considered in this study because they aggregate too large populations. In 1991, the less populated area, Pampulha, numbered 106,330 people. And the highest populated area, the Northwest, in the same year numbered

338,753 people. These areas were also very heterogeneous in terms of exposure to socio-economic and environmental variables.

The 240 "neighbourhoods" (bairros) were not compatible with the census tract, which restrict their use in geographical statistics. Moreover, their boundary definitions are not consistent among the many agencies that work with geographical information, such as: Postal service, Electricity Company, Water and Sanitation Company, Telephone Company, and Municipality Government.

In 1991, the census tracts constituted a network of 1,999 spatial units. It was not used in this study as unit of reference because very small numbers of cases would be drawn in each census tract. In addition, some explanatory variables were not available at census tract level.

The PU network consisted of 81 geographical units (Figure 4-4). It was at an intermediate level between Regional Administrative Areas and neighbourhoods and was compatible with both Regional Administrative Areas and the majority of the census tracts. In 1995, the PU network was redefined by the author in collaboration with Oliveira and Amaral (Oliveira et al, 1996).

The PU network was developed as the geographical base reference when matching different databases related to Belo Horizonte city for urban planning purposes. The criteria used were: limits or physical barriers, use of the land and settlement characteristics. Annex 2 describes the matching process between the PU network and census tracts.

The PU network still represents a heterogeneous population in epidemiological terms. However, the PU network is compatible with Population Census information and it has a higher level of homogeneity than other population aggregation, such as the administrative and neighbourhood networks. Eight PU were totally constituted by favelas.

Figure 4-4 presents the PU network, indicating favelas and non-favelas areas, and PU excluded from the study.

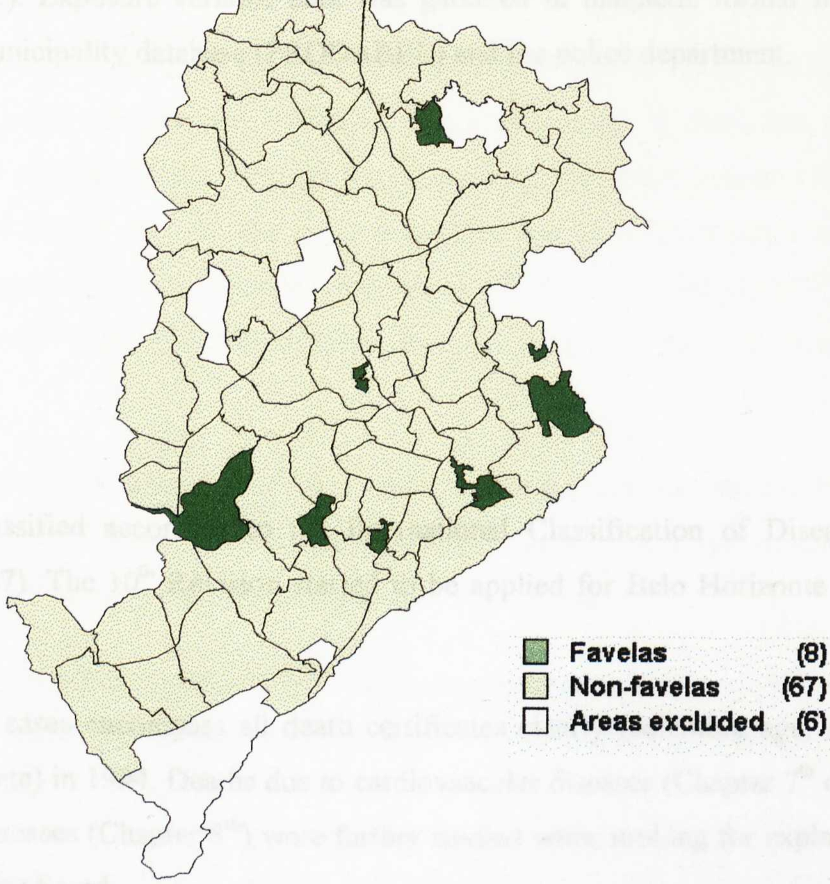

Figure 4-4 F*avelas* and non-favelas planning units, and areas excluded from the study (number of a reas)

4.5 Sources of data

This section presents the sources of data used in this study. It presents concepts and describes the collection procedure and limitation of mortality, population and exposure data. Data from the three sources were geographically matched according to the *planning units* network.

The mortality data section is longer than the others because relates to primary data specially processed for this research. Data related to population was gathered in magnetic format from census bureau (IBGE). Exposure variable data was gathered in magnetic format from the census bureau, the municipality database (PRODABEL) and the police department.

4.5.1 Mortality data

Definition

The deaths were classified according to the International Classification of Diseases 9th Revision (WHO, 1977). The 10th Revision started to be applied for Belo Horizonte data in 1998.

"All-cause of death" cases encompass all death certificates clearly indicating age, sex and address (Belo Horizonte) in 1994. Deaths due to cardiovascular diseases (Chapter 7th of ICD-9th) and respiratory diseases (Chapter 8th) were further studied when looking for explanations of the mortality patterns found.

"Infectious and parasitic diseases diseases" cases refer to all death certificates which underlying cause of deaths was coded from 001-139 (ICD-9th). Those constitute the 1st Chapter of ICD-9th. As mentioned before, AIDS does not belong to that chapter. This disease was not included because it is not associated with physical environmental factors.

"Diarrhoea, pneumonia and malnutrition" refers to all death certificates whose underlying cause of death was coded respectively as 004-009, 480-486 and 260-269.

"External causes of death" refer to all death certificates whose underlying cause of deaths was coded respectively in the "Supplementary Classification of External Causes of Injury and Poisoning". "Homicide" refers to certificates coded between E960 and E969. MVTA refers to certificates coded as E800-E848.

Data collection

The death certificates relating to 1994 were photocopied from the archives of the Fundação João Pinheiro[29] (FJP) and automatically coded for underlying cause of death and address. They were processed in PRODABEL through the Mortality Information System (SIM 4.2) provided by the Ministry of Health. The system codifies the underlying cause of death according to the International Classification of Diseases 9th Revision (WHO, 1977). Only death certificates with full address clearly identified as originating from Belo Horizonte were considered.

Data processing was necessary because the FJP could not produce an electronic database. All data was manually tabulated. Only information regarding to underlying cause of death, age and sex were tabulated. The information referred to the city as whole.

Four fifth-year medical students processed the certificates. Ambiguous information related to underlying causes of death and address were taken to the researcher, who made the final decision about the cases.

Address misclassification is a potential problem in favelas where the addresses are not clearly defined because of the specific socio-environmental conditions, as described in Chapter 2. Table 4-2 computes potential and final cases available for the analysis. Inaccuracies of address were responsible for the exclusion of most of the cases.

Age exclusion occurred when age was not determined in the death certificate. Geographical exclusion happened as a consequence of the exclusion of 6 geographical areas with very small and/or unusual population in 1994.

Duplicates in registries were checked using the software application Access 97. Data cleansing was carried out by the comparing names of the deceased (or name of the mother if name was not present), address, date of birth and underlying cause of death. If more than one record shared three out of the four variables, only one registry was kept (usually the registry presenting the smaller ordinal number). If more than one record shared two variables, they

[29] Fundação João Pinheiro (FJP) was the state government agency responsible for collecting and processing vital data from registry offices until 1998. Since 1999, the health departments of the municipalities assumed this responsibilities under the supervision of the Ministry of Health (MS/FNS, 1999b).

were investigated with the help of the Health Department. The doctors or the nurses responsible for the death certificate was contacted (by phone) in order to clarify if the records referred to twins or duplicates. In case of duplication, only one record was kept following the described procedure.

Table 4-2 Cases included and excluded from analysis

UNDERLYING CAUSE OF DEATH	ALL CAUSES	INFECTIOUS DISEASES (CHAPTER I)	EXTERNAL CAUSES (SUP. CLASSIF. E)
Possible cases according to Fund. João Pinheiro	14,254	735	1,369
Not found	2,665	153	265
Inaccurate address	1,009	61	134
Age exclusion	3	0	0
Geographical exclusion	19	1	0
Final cases	10,558	520	970

Despite the mortality data problems, the data collected for this research was considered satisfactory because of following reasons:

1. Pearson χ^2 was performed[30] for the comparison of the data from the two data sources (this research and FJP) and was not shown to be significant for sex, age and underlying cause of death.

2. Deaths due to homicides are consistent with data collected for a different study (PBH, 1996). The Health Department of Belo Horizonte collected death certificates from homicides in 1994. The department used the PU network for calculating age adjusted homicide rates. The geographical comparison of the mortality rates obtained from this research and the Health Department one showed similar patterns (PBH, 1996).

[30] The test was applied to compare whether there is a difference in trend of the proportions in the two sets of mortality data.

Data limitation

<u>*Data loss*</u>

In Brazil until 1996, the information available in death certificates was sex, age, actual occupation, permanent city of residence, the place where the death occurred, and underlying cause of death. Although present in the document, addresses have never been routinely processed until 1997 in any Brazilian city. Usually "usual city of residence" and "city where the death occurred" are the only geographical data considered by Brazilian demographic information systems. This generic information does not enable checking of the reliability of a given address. Thereby the information system of mortality has been vulnerable to address misclassification[31]. Until 1997, all Brazilian metropolitan areas have been prone to address misclassification.

One type of misclassification found in this research relates to address misclassification, being responsible for an artificial increase in deaths in Belo Horizonte, in the year of the investigation. In 1994, using indirect methods of mortality estimation[32], it was found that 894 extra deaths were possibly registered for Belo Horizonte. Other evidence comes from the data processing: 1,006 death certificates could not be geocoded because the given addresses did not correspond to the comprehensive address directory of the city government. Table 4-3 shows a contradictory trend in number of death both in Belo Horizonte and in surrounding municipalities of the metropolitan region.

[31] Misclassification related to address of the death certificate. The address is given or written incorrectly. This misclassification produces artificially a loss or an excess of deaths in the mortality records.

[32] The estimation was based in the data from 1993 and 1995. The indirect estimation method of mortality is described in SHRYROCK ET AL (1976), pp. 483-510.

Table 4-3 Deaths by residence in the State of Minas Gerais (MG), the City of Belo Horizonte (BH) and other municipalities of the Metropolitan Region of Belo Horizonte (OM), 1991-96

AREA/YEAR	1991	1992	1993	**1994**	1995	1996
MG	87,705	92,884	96,331	**95,544**	94,275	95,773
BH	12,729	13,195	13,093	**14,254**	13,471	13,437
OM	7,260	7,951	8,522	**8,212**	8,541	8,679

Source: MS/DATASUS/FNS/CENEPI (1998)

The Figure 4-5 highlights the mirror image trend in 1994 between Belo Horizonte and surrounding municipalities of the metropolitan region. Between 1991 and 1993 and also in 1995 and 1996, the rise in death are consistent for Belo Horizonte City and other cities within the metropolitan area. Only in 1994, the registered deaths present opposite trends.

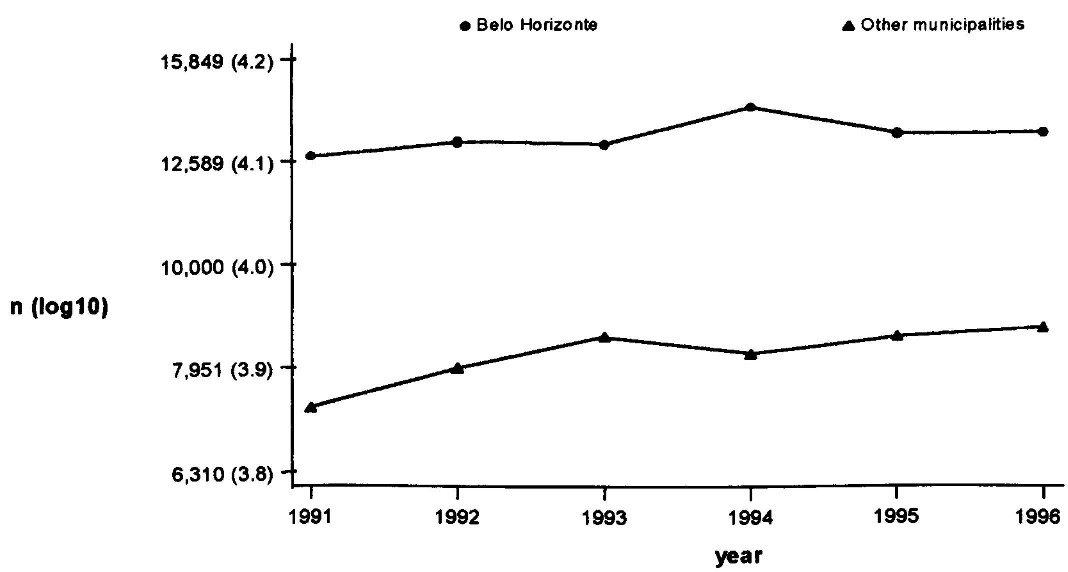

Figure 4-5 Deaths (log) of the City of Belo Horizonte and other municipalities of the metropolitan region of Belo Horizonte (1991-1996)

It is unlikely that Belo Horizonte City presented a mortality rise while the surrounding cities presented a reduction in mortality. Belo Horizonte City has more advanced health equipment, better infrastructure and its population has higher level of education, income and employment. A sudden rise in mortality would indicate epidemics restricted to Belo

Horizonte and not being able to reach the surrounding areas. It is more likely that an outbreak in Belo Horizonte would easily spread among the cities of the metropolitan region.

In addition, Belo Horizonte concentrates a great number of the hospitals of the State of Minas Gerais. Therefore it is feasible that some deaths computed in Belo Horizonte in fact are related to permanent residents of the other cities out of the metropolitan region.

Underlying cause of death

Table 4-4 shows the prevalence of selected causes of death in Belo Horizonte (1994). In all selected causes, vague definitions prevail. In neoplasm, four out of five have an unspecified anatomic definition.

Table 4-4 Rank, frequency (proportion) of selected groups of death in Belo Horizonte in 1994

	total	1st	2nd	3rd	4th	5th
All-causes (All ages)	10,558	489 (4.6%) Acute ill-defined cerebrovascular disease	421 (4.0%) Acute myocardial infarction	350 (3.3%) Pneumonia organism unspecified	276 (2.6%) Congestive heart failure	256 (2.4%) Chronic airways obstruction, unspecified
All-causes (under 5)	1,424	179 (12.6%) Respiratory distress syndrome	108 (7.6%) Bronchopneu. unspecified	96 (6.7%) Respiratory problems after birth	84 (5.9%) Other perinatal infections	72 (4.5%) Unspecified septicaemia
Infectious diseases[1]	520	171 (32.9%) Unspecified septicaemia	90 (17.3%) Chagas Disease	68 (13.1%) Gastro-enteritis of presumed infectious origin	59 (11.3%) Gastro-enteritis of infectious origin	33 (6.3%) Unspecified pulmonary tuberculosis
Neoplasm	1,407	173 (12.3%) Lung cancer, unspecified	132 (9.4%) Stomach cancer, unspecified	126 (9.0%) Breast cancer, unspecified	88 (6.2%) Prostate cancer	67 (4.8%) Unspecified malignant neoplasm
Circulatory System diseases	3,395	489 (14.4%) Acute ill-defined carebrovascular disease	421 (12.4%) Acute myocardial infarction	276 (8.1%) Congestive heart failure	204 (6.0%) Other primary cardiomyopat.	199 (5.9%) Intracerebral haemorrhage
Respiratory System diseases	1,398	350 (25.0%) Pneumonia unspecified organism	256 (18.3%) Chronic airways obstruction	207 (14.8%) Bronchopneu. unspecified	98 (7.0%) Other diseases of lung	88 (6.3%) Bacterial pneumonia, unspecified
External causes	970	218 (22.5%) MVTA, unspecified	130 (13.4%) MVTA involving collision with pedestrians	107 (11.0%) Assault by firearm, unspecified	94 (9.7%) Unspecified accidents	66 (6.8%) Drowning (tank, swimming pool)

[1] Not including AIDS

LADEIRA AND GUIMARÃES (1998) studied 50 deaths due to traffic accidents which occurred in Belo Horizonte between 3rd November and 3rd December of 1994. They found a poor inter-rate reliability between the death certificates and hospital records. 32% of deaths were coded as non-specific accidents and 38% of deaths were coded as non-specific traffic accidents.

MENDONÇA ET AL (1994) identified great problems related to the misclassification of the underlying cause of death in infants for the year 1989 in the Metropolitan Region of Belo Horizonte. They suggest that there is a great interrelation among the major causes of death (pneumonia, diarrhoea, and malnutrition). The synergistic effects of infection-malnutrition make it difficult to come to a medical decision of which is the underlying cause of death.

Reviewing a random sample of 195 deaths from 14 cities within Metropolitan Region of Belo Horizonte, MENDONÇA ET AL (1994) verified that "11.7% of neonatal deaths did not have the underlying cause of death confirmed by the investigation, and neither did 44.0% of post-neonatal deaths" (p.390). CARVALHO ET AL (1990) found a similar misclassification in the Metropolitan Region of Rio de Janeiro.

These limitations led to the use of mortality at a broad grouping level instead of using a more specific underlying cause of death. Hence the data is presented grouped as: all cause of death, infectious diseases, combined diseases for children (diarrhoea, pneumonia and malnutrition), neoplasm, cardiovascular diseases, respiratory diseases, external cause of death, homicides, and MVTA.

4.5.2 Population data

Definition

The population reference of the study was the population of each planning unit in the year of 1994. Population was estimated for each planning unit for the year of 1994. The population was grouped in age intervals of five years for each sex. Exceptionally, the last age interval encompasses population of 75 years and more.

Data from the special population census (1996) combined with Population Census (1991) was used for estimating the population of each planning unit. Annex 4 presents the methods used for estimating population.

Data collection and data limitation

Data from the population censuses was gathered from the census bureau in magnetic format. It was provided at census tract level aggregation. Before to perform the population estimates, data was aggregated at PU level. As explained in the section 4.4, PU and census tract networks of Belo Horizonte became compatible as a consequence of this research.

The main problems in any population census are related to the reliability of the response and enumeration distortion. PEREIRA (1996) has analysed the reliability of sex and age in Brazilian states in the Population Census (1991), and CARVALHO ET AL (1992) have checked the population enumeration in Belo Horizonte using the same Census.

It is known that the female population tends to declare a lower age, and ageing populations tend to overestimate their age. Age unknown is not a particular problem among Brazilian larger urban areas. Age and sex data reliability can be checked by many demographic techniques.

Using Myers' Blended Index[33] PEREIRA (1996) concluded that, in Brazil, age ending in 5 tended to be preferred and age ending in 9 tended to be avoided in the last Population Census (1991). However that phenomenon is associated with presumed age. When the birth date was declared that process was irrelevant. In 1991, in State of Minas Gerais, only 4.8% of counted population could not remember their date of birth. As a consequence they declared a presumed age. Less than 0.1% of Minas Gerais State population could not inform their ages.

CARVALHO ET AL (1992) studied Population Census (1991) coverage and compared address databases from public energy supply and water supply companies, school enlistment, and

[33] Myers' Blended Index is used to measure the presence of age preference in census data (SHRYOCK, 1976). According to PEREIRA (1996) the index measured for Minas Gerais (1991) was 0.4 when date birth was provided and 8.9 when it was not.

birth registry and death certificates. They concluded that alternative sources presented compatible growth data with the Population Census (1991). The possible enumeration distortions were irrelevant for Belo Horizonte City.

4.5.3 Exposure variables

Definition

The exposure variables were classified as socio-economic (Table 4-5), "environmental" related to infectious disease, and "environmental" related to external cause of death.

The variables were defined according to plausibility, availability and (in the final stage) according to their contribution to the statistical regression model i.e., in the last stage of the analysis (the multivariate analysis), the variables to be present in the regression model were selected through stepwise regression[34]. This incrementing process aimed to identify the contribution to each variable to the mortality due to selected causes under the "good" regression model.

Low education of the head of the household was selected as the main proxy of socio-economic status. The two comprehensive socio-economic variables (income of the head of the household and low education of the head of the household) were highly correlated to each other. As a consequence, one of them had to be excluded from the statistical model. Low education was retained in the model for statistical and methodological reasons. Low education presented a normal distribution among the geographical units while income was dramatically high hand skewed, suggesting that high income was concentrated in few geographical units. Education was also less prone to the fluctuations due to economic

[34] *Stepwise regression* belongs to" a series of methods for selecting 'good' (although not necessarily the best) subsets of [exposure] variables when using regression analysis. The three most common used of these methods are *forward selection, backward elimination*, and a combination of both of these known as *stepwise regression...* In the stepwise procedure, variables are entered as with forward selection, but after each addition of a new variable, those variables currently in the model are considered for removal by the backward elimination process. In this way it is possible to that variables included at some earlier stage might later be removed, because the presence of new variables has made their contribution to regression model no longer important" (EVERITT, 1995, p. 232).

instability. Therefore, we assumed that low education status does not change abruptly following good or bad performance in the economy.

Table 4-5 Socio-economic variables, definition and year of reference

VARIABLES	DEFINITION	REFERENCE YEAR	SOURCE
Educational level	Proportion of the head of the household with up to 10 years of fomal education	1991	Census
Income	Average income of the head of the household per month, in US dollars.	1991	Census
Illiterate women	Proportion of illiterate women (15-49 years old)	1991	Census
Women heading the family	Proportion of women heading the family	1991	Census

Table 4-6 presents the variables that may be associated with some infectious diseases. Although related to socio-economic dimension, illiterate women are included in that group because of the role of maternal education in child survival.

Table 4-6 Exposure variables related to infectious diseases, definition, and year of reference

VARIABLES	DEFINITION	TIME REFERENCE	SOURCE
Crowding	Number of persons per room (P/R)	1991	Census
Water supply - link	Proportion of household with distribution internal or external	1991	Census
Sewage	Proportion of household connected to public sewage network	1991	Census
Rubbish collection	Proportion of household with direct rubbish collection	1991	Census
Illiterate women	Proportion of illiterate women (15-49 years old)	1991	Census
Favela	Squatter settlement (favela) - binary variable	1994	GIS/ Prodabel

Table 4-7 presents the exposure variables possibly associated with violence and motor vehicle traffic accidents (MVTA).

Table 4-7 Injury and violence related variables, definition, related dependent variables and time reference

VARIABLE	DEFINITION	DEPENDENT VARIABLE	TIME REFERENCE	SOURCE
Motorways and principal roads	Proportion of motorways and principal roads among the total extension of roads	MTVA	1989	GIS/ Prodabel
Poor illumination	Proportion of poorly illuminated streets (over 40m of distance between two lamp post)	MTVA Homicide	1989	GIS/ Prodabel
Crowding	Number of persons per room (P/R)	Homicide	1991	Census
Police response time	Average of timing of response of a police action after a phone call per area	MVTA Homicide	1994	Police of State of Minas Gerais
Favela	Squatter settlement (favela) – binary variable	Homicide	1994	GIS/ Prodabel

There was considerable correlation between selected socio-economic and physical measures. For example, crowding is also related closely to socio-economic conditions (BRENNAN, 1998). In Belo Horizonte, crowding proved to be extremely correlated with both income and low education, as it is shown in the Results Chapter. Despite being highly correlated with low education, crowding was kept in the statistical analysis because it has also a biological dimension that cannot be covered by low education of the head of the household. Therefore it received a special treatment in statistical model. It was kept in the univariate analysis but was not analysed together with low education. The multivariate models encompassing crowding were undertaken with female illiteracy replacing low education of the head of the family as the socio-economic indicator.

Female illiteracy has two dimensions: it acts as socio-economic indicator and as a proximate determinant for child mortality. The former relates to low educated head of the household as the head herself or as a partner, assuming that uneducated women tend more to marry or leave with low educated or illiterate partners than educated women. The latter refers to the health behaviours used in relation to the children. In this research, women's illiteracy is studied in both ways. In the statistical model, it is used alternatively to low education of the head of the family in the study of crowding effects. In this context, it is studied as a distal determinant. It is also studied as a proximal determinant for children mortality when studying mortality of children (0-4 years).

Favela as variable

In this study, the eight main favelas of the city were compared to the rest of the city, as showed in figure 4-4. Each of them covers the majority of a planning unit, constituting a homogeneous area. The data related to other favelas were diluted within data from their larger planning units. Hence, they could not been used as representative of the favela population.

The variable favela can be a composite indicator for socio-economic and environmental exclusion. In the context of this research, the variable favela was considered as more than a geographic variable. Favela is also the theoretical cut-point for social and environmental inequality. Favelas combine the lack of basic infrastructure with the lowest levels of socio-economic status within Brazilian cities. The favela population has a specific mortality pattern, shaped by socio-economic and environmental conditions. The specific association of environmental exclusion with specific mortality patterns can be observed through statistically controlling the effect of socio-economic variables.

The comparison between the favelas and the rest of the city aimed to analyse the impact of the accepted worst urban environment on the mortality differentials. The favela vs. non-favela is used as proxy of a composite index of inequality on environmental health. This was then compared with the continuous and quintile analysis.

Exposure variables cut points for quintiles

The magnitude of the risk was studied in two forms: continuous values and grouping into quintiles. The continuous values approach implies the comparison of each of planning unit to a baseline. Grouping into quintiles was used more frequently and relates to the grouping of the planning units into quintiles, of 15 planning units each.

Table 4-8 describes the threshold of the exposure variables. The respective cut points were constant during the statistical analysis, when dealing with the quintile approach. The values were obtained after the quintile division. The first quintile always represents the most favourable "healthy" context. For example, the first quintile of "motorways and principal roads" is related to the areas with the smallest proportion of that variable among the total roads. According to the current literature, it is assumed that "motorways and principal roads" are associated with MVTA.

Table 4-8 Exposure variables: cut points

VARIABLES	1ST QUINTILE	2ND QUINTILE	3RD QUINTILE	4TH QUINTILE	5TH QUINTILE
Low education (%)	≤ 49.4	-74.2	-82.3	-90.7	> 90.7
Monthly income (US$)	≥ 628	- 370	- 224	-161	< 161
Woman heading the family (%)	≤ 18.4	- 20.9	- 24.4	-28.3	> 28.3
Illiterate women (%)	≤ 2.4	-4.7	-5.8	-8.9	> 8.9
Water supply – link (%)	≥ 96.2	-94.7	-92.7	-86.1	< 86.1
Sewage (%)	≥ 95.3	-92.4	-89.1	-85.2	< 85.2
Rubbish collection (%)	≥ 94.3	-89.7	-85.6	-67.4	< 67.4
Motorways and principal roads (%)	≤ 5.2	-8.5	-12.3	-15.0	> 15.0
Poor public illumination (%)	≤ 6.1	-10.0	-14.0	-17.5	> 17.5
Crowding (person/room)	≤ 0.5	-0.6	-0.7	-0.9	> 0.9
Police response time (minutes)	≤ 200	- 292'	- 411	- 573	> 573

In addition to the study of impact of each variable, the following section presents a brief discussion of the variable *favela* because of its specificity as a variable and social phenomenon.

Data collection and data limitation

The data was collected from the Census Bureau, PRODABEL and the police department. The data was processed at PRODABEL and matched using GIS techniques.

Environmental and socio-economic data gathered from population census (1991) had the same degree of coverage as the population data mentioned above. Grouping the households per planning units reduced the effect of misclassification bias of exposure variables. In this case, incorrect response from a household is diluted by correct response of the neighbour households. The main problem related to an ecological analysis is the ecological fallacy, and this is considered in Section 4-6.

The variables "motorways and principal roads", "poor public illumination" and "favelas", provided by PRODABEL, were defined from aerial photos that were shot in 1989. In 1991, the images were totally processed and presented in digital format. Areas where the images were not clear due to shadows from buildings or trees were visited by PRODABEL. Supplementary information from these areas was collected using traditional methods of measurement. The main limitation of this data is the difference between the year when the photos were took (1989) and the year of the study (1994). This tends to produce an overestimated measurement of the deficiency of public illumination in the areas of recent occupation.

Data provided by the police department encompassed more than 400 thousand registries for the year of 1994. Data was geocoded in PRODABEL. The overall frequency and frequency for the central area of the city for the year of 1994 was consistent to the years 1993 and 1995. The main limitation related to this data is that all calls were considered. It was assumed that the pattern of response would remain similar if only high priority calls (such as attempted homicide) were considered. However this type of computing simulation was not performed. It is possible that the type of call could interfere in the time of assistance among the areas.

4.6 Analysis

The variation of exposure variables across the planning units is initially studied through describing the values of each exposure variable in relation to the 5th, 50th and 95th percentiles, and the maximum value. The 75 values related to the equivalent number of planning units were sorted in ascending order, obtaining the non-integer values through linear interpolation of the neighbouring values (CANOVER, 1980).

Spearman's rank correlation was used to study how each exposure variable correlates to each other. The method implies that the values, related to each exposure variable, should be converted to rankings because none of the variable distributions seemed normal (SNEDECOR AND COCHRAN, 1989). The values are presented in a correlation matrix form (Table 5-2). Taken separately, each of the values in the matrix describes the strength of the linear relationship between each pair of variables involved (Keinbaum et al, 1998). In the matrix, the values can range from –1 (complete discordance) to +1 (complete concordance). If the value is close to 0, there is little evidence of linear association, indicating a nonlinear association or no association at all (KLEINBAUM ET AL, 1998).

The mortality ratios were standardised by five-year age and sex, using mortality rates for urban population of the State of Minas Gerais (1991) as reference. For descriptive techniques, direct methods of standardisation were used[35], allowing for comparisons of the planning units that have different age structures. Mortality rates derived from indirect methods are known as

[35] Direct standardisation refers to the process of adjusting a crude mortality rate by age and sex, by using as the reference the urban population of the State of Minas Gerais (1991). "Age-specific death rates derived from each [planning unit] would be applied to the [reference] population age distribution, to yield mortality rates that could be directly compared" (EVERITT, 1995, p.76). In this work, mortality rates produced trough direct standardisation are written as Age and Sex Standardised Mortality Rate or Sex Standardised Mortality Rate, if encompassing only one age-group.

the Standardised Mortality Rates (SMR)[36]. The SMRs were used for mapping mortality within Belo Horizonte.

For analytical techniques, only indirect methods of standardisation were used. In this context, the SMR were used to produce mortality rate (MR) ratios through Poisson regression methods[37].

Descriptive techniques (proportionate mortality rate, crude mortality rates and mortality ratios) summarised the mortality due to selected causes across the PU. Mortality mapping was also used to complement the descriptive analysis.

Analytical techniques (mortality rate ratios calculated through Poisson regression methods) were used to calculate mortality differentials among the planning units in relation to exposure differentials. Poisson regression analysis was firstly performed to study the univariate relationship between exposure variables and MRs.

In this work, mortality rates and mortality rate ratios usually refer to all ages and both sexes. Although, in three circumstances age and/or sex adjusted mortality rates were separately calculated. For deaths due to all-causes and cardiovascular diseases, mortality rate (MR) ratios were calculated for 15-64 and 65 and over age-groups and for sex. For deaths due to respiratory diseases, MR ratios were calculated for sex. For deaths due to diarrhoea, pneumonia and malnutrition, MR ratios were calculated for 0-4 age-group.

The Poisson regression approach was subsequently used in multivariate analysis for studying the relationship between socio-economic and physical environmental variables and mortality due to infectious diseases and external causes of death. The objective was to measure the contribution of each socio-economic and environmental variable to the health inequality in Belo Horizonte.

Part of the multivariate analysis evolved the categorisation of the planning units into quintiles. That level of grouping was chose when considering the number of geographical areas and cases included, e.g., it allows for good discrimination and avoids categories with small or null values. Each quintile encompasses 15 geographical units classified according to

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[36] Standardised Mortality Rates (SMR) are defined as "the number of deaths, either total or cause-specific, in a given population, expressed as a percentage of the deaths that would have been expected if the age and sex-specific rates in [urban population of the State of Minas Gerais in 1991] had applied" (EVERITT, 1995, p.245).

low education and physical environmental explanatory variables. The baseline was always defined as the most favourable circumstance in health terms. For example, for the variable "proportion of low educated head of family", the baseline was the quintile with the lowest proportion of low educated head of the family. For the variable "proportion of the households linked to public water system" the baseline was the quintile with the highest proportion. As consequence, all MR ratios represent the risk difference between the less favourable geographical units and the most favourable ones.

In the Chapter 5, two graphic types (plot at error bar and two-way scatter plot) are used to summarise the univariate analysis. In the plot at error bar type graphics, points indicate the MR ratios calculated using Random Effect Poisson methods. The connected lines mark the confidence interval at 95%. The geographical units are grouped into quintiles. For comparison purposes, the most favourable quintile represents the base line. The two-way scatter plot type summarises the univariate analysis performed for measurement of the association between MR ratios and selected explanatory variables. The points indicate the MR ratios of 75 geographical units. The Y line represents the values of the estimated Poisson regression line corresponding to the observed MR ratios.

The tables related to multivariate analysis contain three columns of MR ratios for quintiles: (a) ratios standardised for age and sex; (b) ratios additionally adjusted for low education; and (c) ratios further adjusted for all other environmental characteristics. The calculation performed for ratios mentioned in the items (b) and (c) were performed under Random Effect Poisson Regression. That statistical procedure was performed for dealing with overdispersion of SMR.

Overdispersion, also known as extra-Poisson variation, occurs as consequence of unmeasured or unknown variables (CLAYTON AND HILLS, 1996, HILLS, 1996). Therefore, the width of the confidence interval decreases, producing less realistic values.

The inadequacy of the Poisson model, due to overdispersion, was observed in significance of the goodness-of-fit χ^2 for mortality models allowing for explanatory variables[38]. The

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[37] *Poisson regression [method]* is a regression technique available for modelling dependent variables that describe discrete data (KLEINBAUM ET AL, 1998, p.687).

[38] The Goodness-of-fit test was used for comparing two models, one of them allowing for explanatory variables related to overdispersion. This more complicated model presented a better fit for the data.

mortality models were further tested in a negative binomial model[39]. The found χ^2 values asserted that the data could not follow a Poisson distribution.

The P-value for linear trend can be seen either on the right hand column or if insufficient space in the bottom of the tables. That refers the statistical test for linear trend of O/E ratios across the levels of each explanatory variable in the model. This is the only situation in the tables that values for each planning unit are considered, not being referred to quintiles.

The statistical analysis was carried out using the statistical package Stata. Either version 5.0 or version 6.0 was used. Stata Corporation developed the package.

Two softwares were used for geographical analysis: Apic 3 and MapInfo Professional (4.5.2). Apic 3 was used for developing the geographical layers of data, including geocoded mortality data. MapInfo was used for constructing the maps. Apic was developed by Apic Systems, and was used in the geographical information system (GIS) laboratory of PRODABEL (Belo Horizonte). MapInfo was developed by MapInfo Corporation, and was used in the GIS laboratory of the London School of Hygiene and Tropical Medicine (London).

[39] Negative binomial model estimates random-effects overdispersion models. It assumes that the dispersion is the same for all elements in the same group, varying randomly from group to group (STATACORP, 1999).

Chapter 5 - Results I

This chapter is divided into three parts. The first part describes the characteristics of the planning units and the possible relationships among the exposure variables. The second part is divided into two sections.

The first section presents the simple measurement techniques of mortality i.e. sex and age adjusted mortality rates and proportionate mortality. The second examines the distribution of socio-economic and environmental variables and mortality rates across the planning units, using mapping techniques. The last part presents the results obtained using analytical techniques.

5.1 Characteristics of the study area

This section provides a description of the characteristics of the 75 studied *planning units*. The characteristics were classified as demographic, socio-economic and physical environmental.

5.1.1 Demographic characteristics

The Figure 5-1 shows the changes in the areas classified in 1st and 5th quintiles according to the proportion of low educated heads of the household in 1991. The same areas are reviewed using 1996 data. The 1st quintile contains areas with the lower proportion of low educated heads of the household. The 5th quintile contains areas with the highest proportion of low educated heads of the household. Each quintile contains 15 areas. This particular aspect involving epidemiological transition will be further discussed in the section 7.4.1 (Chapter 7).

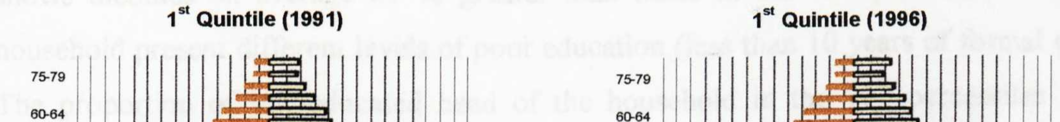

Figure 5-1 Age structure according to the proportion of low-educated head of the household in Belo Horizonte (1991 and 1996)

Population size is presented for three age groups in Table 5-1: children (0-14 years old), youth/adults (15-64 years old) and the elderly (65 years old and over). Population size varies in the planning units. The 95th percentiles related to children and youth/adults are respectively 21.66 and 19.35 times greater than the 5th quintiles. However the highest variation occurs in the elderly group. The 95th percentile is 46.13 times greater than the population size of the 5th percentile.

5.1.2 Socio-economic characteristics

The income average of the head of the household (US$) is skewed on the tail, i.e., the highest income is concentrated in a few planning units. The area with the wealthiest households shows incomes on average 63 % greater than those in the 95th percentile. Heads of the household present different levels of poor education (less than 10 years of formal education). The proportion of low-educated head of the household in the 95th percentiles is 6 times greater than in the 5th percentile. The proportion of illiterate female (15-49 years old) in 95th percentile is 2.5-fold the proportion in the 5th percentile.

5.1.3 Physical environmental characteristics

Crowding is present when the index (persons per room) is over 0.5. Among the areas, the average and the median are higher than 0.5 (Table 5-1). Crowding is also highly correlated to education variables and income.

The proportion of households linked to water systems and to sewage systems are high. Most of the population of Belo Horizonte seems to have access to water and sewage systems. However, in the 5th quintile, one fourth of the households lacks the direct access to water and sewage systems.

Table 5-1 Summary of demographic, socio-economic, physical environmental, and other characteristics in the 75 planning units studied (Belo Horizonte)

Variables	year of reference	Mean (s.d.)	Percentile 5th	50th	95th	Maximum
DEMOGRAPHIC						
0-14 years (n)	1994	7,635.61 (5,284.14)	862	6,833	18,668	20,432
15-64 years (n)	1994	18,322 (12,326.99)	2,278	16,987	44,084	46,393
65 and more (n)	1994	1,414.53 (1,273.02)	97	1,032	4,475	5,719
SOCIO-ECONOMICS						
Income (US$)	1991	427.68 (449.52)	102.27	247.77	1,390.27	2,261.24
Low-educated (%)	1991	69.15 (25.67)	16.02	77.71	96.21	97.12
Female illiteracy (%)	1991	6.13 (4.40)	1.62	4.51	15.53	18.31
Female as head of the household (%)	1991	23.66 (6.62)	14.60	22.37	36.33	49.49
PHYSICAL ENVIRONMENT						
Crowding (persons/room)	1991	0.68 (0.22)	0.34	0.69	1.08	1.24
Water (%)	1991	90.23 (8.83)	67.71	93.37	98.26	98.56
Sewage (%)	1991	89.23 (7.18)	74.1	91.44	97.98	98.85
Rubbish (%)	1991	79.44 (20.98)	31.05	88.40	96.93	98.65
Main roads (%)	1989	11.47 (8.33)	1.21	9.63	31.15	38.57
Poor Illuminat[1]. (%)	1989	12.57 (7.43)	2.72	11.88	28.98	36.85
OTHER						
Police response (minutes)	1994	386.56 (220.18)	35.23	321.36	824.25	889.20

[1] Areas illuminated by post lamps, each one with more than 40 meters of distance from the other

Access to door-to-door rubbish collection is on average 80% for all planning units. However, in the 5th percentile, 70% of the households lack access to this service.

The proportion of motorways and primary roads (main roads) varies dramatically among the planning units. The 5^{th} percentile presents 1.21%, while the 95^{th} percentile present a proportion 26 times higher.

Poor illumination has a high variation among planning units. In average only 12.57% are poorly illuminated. However, the 95^{th} percentile has a proportion of poorly illuminated roads 10.65 times higher than the 5^{th} percentile.

5.1.4 Other characteristics

The police response to phone calls varies among the areas. On average, it requires over 6 hours for the calling household to be assisted by the police. The 5^{th} percentile requires 34 minutes, while the 95^{th} percentile requires more than 13 hours.

5.1.5 Mapping socio-economic and environmental characteristics

Annex 5 contains maps of the socio-economic and environmental characteristics and of mortality of the Belo Horizonte's planning units (PU). The first figure of the Annex, Figure A5-1, presents the map containing the names of the planning units.

Figure A5-1 shows the planning units of Belo Horizonte. In the centre of the map, there is the central area of the city delimited by Avenida do Contorno [Contour Avenue], and constituted by four PUs: Centro, Francisco Sales, Savassi and Barro Preto. As was explained in the previous chapter, it constitutes part of the core of the city.

Figure A5-2 shows the population concentration within the city (population of UP at 1994 divided by area of UP in hectares[40]). It indicates that the favelas and the non-favelas PU surrounding the central area are highly dense. In the periphery of the city, the PU present populations more sparsely distributed.

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[40] 1 hectare (ha) is equal to 3.86 square mile. 100 ha is equal a 1 km^2.

In general, the socio-economic characteristics present a marked pattern in Belo Horizonte: Pampulha and the non-favela PUs that belong or are next to the central area present the best indicators. The worst indicators are found in the favelas and periphery PUs from the North and North-Eastern, and South borders of the city. Proportion of low-educated head of the household follows this pattern absolutely (Figure A5-3). Female illiteracy presents a relatively high proportion in two affluent areas, Mangabeiras and Pampulha (Figure A5-4). Both areas present a proportion of over 4 % of illiterate females (15-49 years old).

The distribution of the crowding indicators across the PUs is similar to the distribution of low-educated head of the households (Figure A5-5). The polarisation pattern is still present for the variables related to water, sewage and rubbish collection. However, there are some nuances in relation to each of these variables. Again the affluent areas of Pampulha and Mangabeiras present up to 13% of households disconnected to public water system (Figure A5-6). Access to the public sewage system is also a problem for Pampulha. Up to 15% of its households are not connected to the public system (Figure A5-7). The map related to the access to rubbish collection indicates that favela Prado Lopes, different from the other favelas, has adequate rubbish collection (Figure A5-8).

The favelas and PUs in the North border of the city presented a proportion of motorways and primary roads under 5% (Figure A5-9). That contrasts with the proportions presented by PUs across an axis, constituted by three motorways, that link the central area (inclusive) and the west side of the city, where the industrial pole of the Metropolitan Area is located. These PUs present above 14% of motorways and primary roads among the whole road network.

In the central areas and the surroundings, excluding most of the favelas, the proportion of poorly illuminated roads is less than 7% (Figure A5-10). That contrasts to the PU in North and North-Easter borders where the proportion is over 18%. This is also the context of two favelas: Prado Lopes and Barragem.

Access to the police (Figure A5-11) is measured by time (in minutes) to be attended by a police office after a telephone call. Figure A5-11 presents an inverse figure than the map related to low education (A5-3). In 1994, Favelas and the PUs in the South border presented a response time less than 207 minutes, while central areas, Pampulha, Mangabeiras and Belvedere had a response time over 582 minutes.

5.2 Correlation among the exposure variables

Table 5-2 summarises the correlations among the exposure variables. Planning units were ranked according to each exposure variable, using Spearman technique (CANOVER, 1980). The correlation matrix helped to define the variables used in the multivariate analysis model. In fact, all characteristics but the demographic ones were exposure variables within the statistical model.

"Income of the head of the household", "low-educated head of the household" and female illiteracy are highly correlated (Table 5-2).

The correlation between income and education was extremely high. Low education is inversely correlated to low income. In this context, both variables are possibly measuring the same process, i.e, education predicts access to remunerative employment. That led to the exclusion of the income variable from the statistical analysis as was explained in the Methods Chapter.

Crowding is also extremely correlated to income and low education. It was retained in the univariate analysis but analysed in a different way during the multivariate analysis. This was also explained in the Chapter 4 - Methodology.

Water, sewage and rubbish collection are also correlated (Table 5-2). The correlation of those variables is not a surprise because the poorer areas in general tend to have low coverage of urban services. What is surprising is the fact that they are not more closely correlated to socio-economic variables. This is related to some historical and topographical aspects of the city as presented in Methods Chapter (section 4.2.1).

Table 5-2. Planning Units (Spearman) rank correlation of selected social and environmental variables

	income	low educated	female illiteracy	female heading	crowding	water	sewage	rubbish	motorway	poor illumination	police response
Socio-economic variables											
income	1.0000										
low educated	-0.9788	1.0000									
female illiteracy	-0.7801	0.8138	1.0000								
female heading	0.1112	-0.1933	-0.3083	1.0000							
Physical environmental variables											
crowding	-0.9780	0.9810	0.8406	-0.1954	1.0000						
water	0.4988	-0.5288	-0.7302	0.0494	-0.5427	1.0000					
sewage	0.6536	-0.6824	-0.7467	0.0472	-0.6786	0.8358	1.0000				
rubbish	0.6707	-0.7017	-0.8069	0.4430	-0.7344	0.6602	0.6809	1.0000			
motorway	0.5664	-0.5484	-0.5561	-0.0323	-0.5893	0.3215	0.4320	0.3786	1.0000		
poor illumination	-0.5067	0.5547	0.7026	-0.5465	0.5815	-0.4819	-0.4496	-0.6467	-0.2232	1.0000	
Other											
police response	0.6947	-0.7267	-0.6943	0.2347	-0.7361	0.5106	0.5986	0.5759	0.4637	-0.5830	1.0000

5.3 Descriptive techniques

This section presents the mortality rates by using descriptive techniques. Additionally, it presents maps related to SMR in the final section. The descriptive techniques encompass proportionate mortality, age and sex adjusted mortality rates and SMR maps.

5.3.1 Mortality Patterns in Belo Horizonte (1994)

Belo Horizonte presents a mortality pattern similar to Brazil as a whole while other Brazilian capitals present important differences usually related to infectious diseases, perinatal causes, external causes and neoplasm.

Table 5-3 compares the main causes of death in Brazil, Belo Horizonte City, Porto Alegre City and Belém City. The other two cities are capitals of Brazilian states as is Belo Horizonte. Porto Alegre is a capital in the Southern wealthier region and Belém is from the Northern poorer region. The population range of the three cities ranges from 1,1 to 2,1 millions. The estimations on the encompassed table only defined causes of death. Ill-defined conditions were not signalled on Table 5-3. The table presents significant variation across the columns. In relation to Brazil, Porto Alegre has lower percentages for infectious diseases, perinatal causes and external causes, presenting higher percentage for neoplasm. Belém presents higher percentages of infectious diseases and perinatal than Brazil.

In relation to Brazil, Belo Horizonte City's percentages show consistency across the columns. Only in relation to external causes is there an important difference. In Belo Horizonte, the contribution of external causes to overall mortality is lower than in the whole country.

Table 5-3 Proportionate mortality according to main defined causes of death in Brazil, Belo Horizonte City, Porto Alegre City and Belem City – 1995

Diseases	Brazil	Belo Horizonte	Porto Alegre	Belém
Diseases of Circulatory System	32.7	32.5	33.9	31.2
Other Defined Causes	17.4	18.5	20.3	16.8
External Causes	15.3	11.5	9.9	10.3
Neoplasm	13.2	14.4	19.3	14.4
Diseases of Respiratory System	11.1	12.8	12.5	10.7
Infectious and Parasitic Diseases[1]	5.2	4.4	2.0	7.1
Perinatal Problems	5.1	5.9	2.1	9.5
Total	100	100	100	100

Source: Ministério da Saúde/FNS/CENPI (1998)
[1] AIDS not included

In Belo Horizonte City, as in Brazil, there is a marked geographical polarisation. In one hand, there are favelas, representing the areas with unfavourable conditions. On the other hand, there are areas with high socio-economic and environmental standard (South-Centre and Pampulha). This allows for a geographical analysis of the socio-economic, environmental inequalities and their impacts on health.

Aggregating data does not reveal this polarisation, because, as STEPHENS ET AL (1994) showed for São Paulo, the poor population is experiencing a double burden of disease. But, the wealthier population is facing an advanced pattern of mortality, dominated by cardiovascular diseases and neoplasms. While poor populations are dying because of a pattern that encompasses both infectious and cardiovascular diseases, rich populations die because of a pattern where the contributions of infectious diseases and perinatal causes are very low.

Figure 5-2 presents proportional mortality rates according to the main causes of death in Belo Horizonte City, from 1900 to 1995. Data related to the years 1990 and 1995 were gathered from DATASUS (1999). Data from other years were extracted from MALETTA (1997). The main conclusions are:

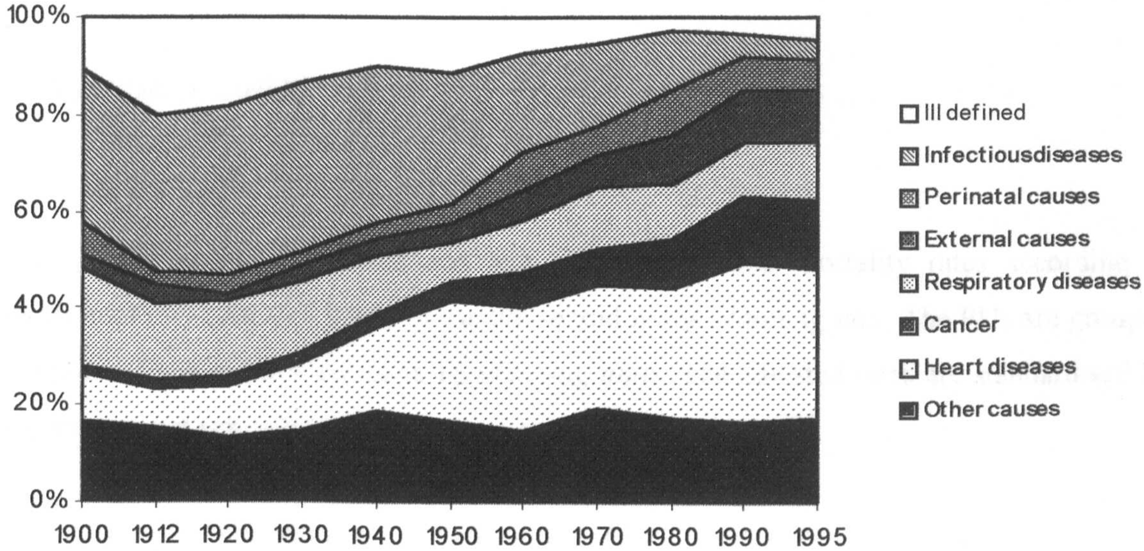

Figure 5-2 Relative distribution of deaths, by cause, in Belo Horizonte. 1900-1995

1) Ill-defined causes declined sharply from 1912 to 1980. However, since 1980 they have slightly risen.

2) Between 1900 and 1940 infectious diseases (diarrhoea and tuberculosis) and respiratory diseases (broncopneumonia) were the main causes of death (MALLETA, 1997).

3) Between 1940 and 1950, tuberculosis followed by diarrhoea are the leading causes, and heart failure became the third most frequent cause of death (MALETTA, 1997).

4) From 1950 onwards, diseases of the circulatory system took on the leading cause of death from infectious diseases.

5) Since 1960, external causes and cancer have risen as important causes of death.

6) Infectious diseases, and possibly perinatal problems are declining.

Figure 5-2 presents a clear trend: Belo Horizonte is moving at fast pace toward a modern pattern of mortality. However, what is hidden within that picture is that the gains, the pace and process vary according to socio-economic status of the population.

5.3.2 All causes mortality

Table 5-4 shows the unadjusted and age and sex adjusted mortality rates according to proportion of low educated heads of the household in the *planning unit*. The PUs are grouped by quintiles. Each quintile contains 15 *planning units*. The adjusted rates are standardised by five-year age and sex.

Table 5-4 Population, deaths, all cause mortality rate (unadjusted and adjusted by age and sex) according to low-educated head of the household (/10,000) in Belo Horizonte (1994)

	Low educated heads of household - quintiles					Total
	1st (low proportion)	2nd	3rd	4th	5th (high proportion)	
population	327,887	501,068	450,878	455,200	317,906	2,052,939
deaths	1,735	2,813	2,352	2,212	1,446	10,558
crude rates	52.91	56.14	52.16	48.59	45.49	51.43
adjusted rates	**37.27**	**50.37**	**55.08**	**57.29**	**58.01**	**50.99**

Figure 5-3 broadly shows that the age and sex adjusted mortality rates tend to increase in the most deprived areas. The difference between the quintile with low proportion of low-educated head of the household (1st) and the subsequent quintile (2nd) tends to be wider than the difference among the subsequent ones.

That pattern is repeated for the age groups 15-64 and 65 and over years old (not shown). For children (0-4 years old), the difference between the quintile with the high proportion of low-educated (5th) and the 4th quintile is the widest (Figure 5-3). Among the all other age groups (not shown) the differences between the 5th and the 4th quintiles are non-significant.

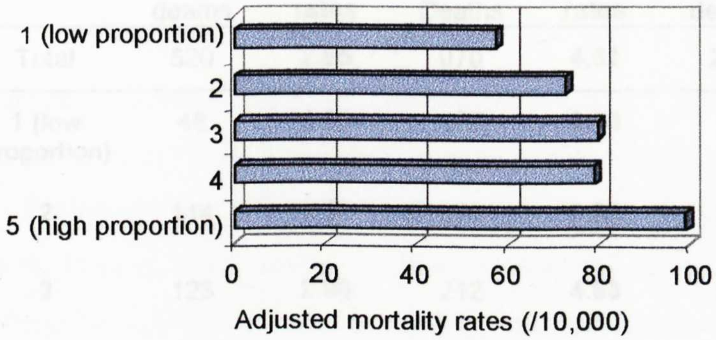

Figure 5-3 All cause sex adjusted mortality rates (0-4 years at death) according to low-educated head of the household (quintiles) Belo Horizonte (1994). N = 1,424

5.3.3 Cause-specific mortality

Table 5-5 shows specific age and sex adjusted rates. It focuses on deaths due to infectious diseases, external causes, homicide, and MVTA. In general, populations from the planning units with a high proportion of low-educated heads of the household experience higher mortality rates for all selected causes. In terms of the unequal distribution of the deaths, there is a gap between the 1st (low proportion of low-educated) and 5th (high proportion), indicating an unequal mortality pattern. In comparison to the 1st quintile, the 5th quintile presents an evidently higher mortality for all selected causes, such as: 2.7-fold (infectious), 1.9-fold (external), 4.1-fold homicide, and 1.5-fold MVTA.

Table 5-5 Selected age and sex adjusted mortality rates (/10,000) according to low-educated head of the household (quintiles) in Belo Horizonte (1994)

Quintile	infectious		External		homicide		MVTA	
	deaths	**rates**	Deaths	**rates**	deaths	**rates**	deaths	**rates**
Total	520	**2.65**	970	**4.61**	232	**1.09**	378	**1.81**
1 (low proportion)	48	**1.38**	107	**2.93**	17	**0.51**	42	**1.11**
2	114	**2.28**	214	**3.97**	37	**0.70**	93	**1.75**
3	123	**2.90**	212	**4.63**	53	**1.11**	83	**1.83**
4	126	**3.17**	271	**6.01**	56	**1.20**	112	**2.50**
5 (high proportion)	109	**3.85**	166	**5.50**	69	**2.09**	48	**1.72**

Figure 5-4 shows sex adjusted mortality rates due to combined illnesses of diarrhoea, pneumonia and malnutrition for children under 5. The rates increase in the areas where there is high proportion of low educated heads of the household. The 5th quintile presents a mortality 3.1-fold greater than the baseline.

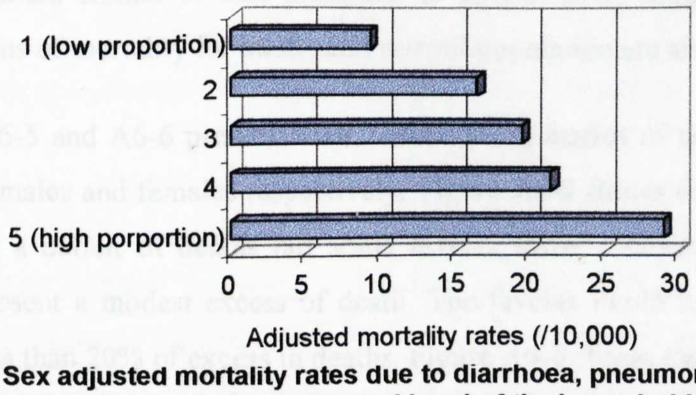

Figure 5-4 Sex adjusted mortality rates due to diarrhoea, pneumonia and malnutrition (0-4 years at death) according to low-educated head of the household (quintiles) Belo Horizonte (1994). N = 362

The results suggest that demographic and epidemiological patterns vary according to the socio-economic status of the planning units. The environmental trends are also consistent with the demographic and epidemiological variations.

5.3.4 Mapping SMRs

Annex 6 contains maps of Standardised Mortality Ratios (SMR) of the Belo Horizonte's planning units (PU). The mortality maps present the Standardised Mortality Rates (SMR) for each planning unit (PU). The SMR present the ratio of the observed deaths over the expected ones. In most of the cases, the favelas presented an excess of deaths while the central area, Mangabeira, Belvedere and Pampulha presented rates bellow 1, indicating a number of deaths lower than those expected.

Figure A6-1 presents SMRs related to all causes of deaths, for all ages and both sexes. The favelas and Capitão Eduardo present from 20 to 140% additional deaths while central area, Pampulha, Mangabeiras and Belvedere present rates from 15 to 50% under the expected.

Figure A6-2 presents the distribution of SMRs of the children under 5. The favelas and some of the PUs in the periphery of the city present excess of death over 20%. The affluent Mangabeiras presented the highest mortality rate. In this case, the number of deaths involved is also high (9 deaths).

Maps related to 15-64 age group for both males (Figure A6-3) and females (Figure A6-4) present pattern similar to that presented in figure A6-1, suggesting that the geographical distributions of mortality for adults and overall population are similar.

Figures A6-5 and A6-6 present SMR related to all causes of death for the 65 and over age group for males and females respectively. Figure A6-5 shows that the central areas were still presenting a deficit of deaths but some favelas show a different pattern. In this map the favelas present a modest excess of death. The favelas Prado Lopes, Barragem and Cafezal present less than 20% of excess in deaths. Figure A6-6 shows Capitão Eduardo with a marked deficit of deaths and some favelas (Morro das Pedras and Barragem) with excess of deaths less than 15%.

Figure A6-7 presents SMR related to infectious diseases for all ages and both sexes. It shows that the favelas, excluding Prado Lopes and Jardin Felicidade, present an excess of deaths over 40%. The affluent Pampulha presented a modest excess of death (11%).

Figure A6-8 present SMR related to deaths due to combined illnesses of diarrhoea, pneumonia and malnutrition for children under 5 years old. The favelas, excluding Prado Lopes and Jardin Felicidade, present an excess of deaths over 55%. The affluent areas Pampulha and Mangabeiras also present an excess of deaths on the same level as the favelas. However, these SMR involve few deaths: 3 deaths each area.

SMR related to external causes of deaths for all ages and both sexes are presented in the figure A6-9. The favelas present an excess of death over 31%. Excess of homicides (over 68%) are also present in all favelas (Figure A6-10).

Figure A6-11 present SMR related to Motor Vehicle Traffic Accidents (MVTA) for all ages and both sexes. The favelas, excluding Cabanas, present over 40% fewer deaths than the expected.

In the following section, random effects Poisson techniques will be used in the study of correlation between socio-economic and environmental variables and outcomes. The section will initially present the relationship between socio-economic variables with all causes of death. It will subsequently focus on the association of mortality due to infectious diseases, diarrhoea, pneumonia and malnutrition, external causes, homicide and MVTA, and socio-economic and physical environmental variables.

5.5 Analytical techniques (Poisson regression methods approach)

This section analyses the relationship between socio-economic and physical environmental variables and selected mortality risk ratios, using the Poisson regression methods. The associations between the proportion of low-educated head of the household and all cause of death (all ages and adults), cardiovascular diseases and respiratory diseases are investigated.

The associations between all causes of death (0-4 years old), infectious diseases, external cause of deaths and socio-economic and physical variables are also investigated.

In this section, tables present the correlation between selected SMRs and selected exposure variables (by quintiles). The baseline (1^{st} quintile) is always represented by the most favourable situation. The tables present population, unadjusted and adjusted ratios and P-value for trend Mortality rate (MR) ratios are presented at three levels of control by other variables. Firstly, ratios controlled by sex and age (when appropriate) are listed. Secondly, ratios are further controlled by the proportion of low-educated head of the family or female illiteracy (when studying crowding effect) and under random effects model. Finally, ratios are further controlled by all other variables. This process aims to identify the contribution of each variable to the mortality due to selected causes. It allows for distinguishing the effect of the socio-economic variables from the physical environmental variables.

5.5.1 All-cause of death

Children (both sexes): all causes

Table 5-6 shows population, deaths, MR ratios related to all causes of death for children under 5 (both sexes) according to the proportion of low-educated head of the household. The table indicates a clear and significant trend of correlation between mortality and low education. Children from areas with the high proportion of low-educated head of the household have a 72% greater chance to die than their counterparts from the baseline areas.

Table 5-6 Population, deaths, and relationship between all-cause mortality rate ratio according to low-educated head of the household (quintiles), under random effect model, under 5 years old. Belo Horizonte (1994)

Quintiles	population	deaths	MR ratios (95% CI)	P-value for trend
1 (low proportion)	17,690	102	1.00	
2	38,875	282	1.23	
3	41,145	327	1.34	0.00
4	45,284	357	1.33	
5 (high proportion)	35,941	356	1.72	

Adults (males and females): all causes

Table 5-7 shows population, deaths, MR ratios due to all causes of death (under the random effect model). It shows MR ratios for male and female, and for 15-44 years old and 65 years old and over. The gender differential in mortality is wider for baseline *planning units* (1st quintile) than for those with high proportion of low-educated head of household. For females, the number of death increases in the elderly age group. However, the differences are less evident in the 5th quintile. For males, only the baseline *planning units* present an increase of mortality in the elderly age group. For other *planning units*, the number of deaths decreases in the elderly age group. Within the 5th quintile, the elderly age group presents only 57% of cases presented by the younger group. That may suggest that mortality is higher for males of all social groups in the adult early life stage.

The socio-economics variables show a strong correlation to all causes of death in all sub-groups for adults and the elderly. Mortality differences are generally larger for females. In general, the findings suggest that the relative excess of mortality is most evident for females (15-64 years at death). For both sexes, the magnitude of differences decreases in the aged group.

Table 5-7 Population, deaths, and relationship between all-cause mortality rate ratio according to low-educated head of the household (quintiles), under random effect model. Male, female, 15-64 and 65 and over years at death. Belo Horizonte (1994)

Quintile	Male			Female		
	pop.	deaths	MR ratios (95% CI)	pop.	deaths	MR ratios (95% CI)
15-64 years						
1 (low proportion)	102,269	360	**1.00**	131,711	178	**1.00**
2	158,456	753	**1.47** (1.25-1.75)	183,993	408	**1.77** (1.47 - 2.13)
3	143,007	661	**1.52** (1.28-1.82)	158,308	340	**1.87** (1.54 - 2.26)
4	144,360	694	**1.66** (1.39-1.98)	154,168	393	**2.35** (1.95 - 2.83)
5 (high porportion)	96,333	408	**1.59** (1.32-1.92)	101,573	258	**2.46** (2.02 - 3.00)
≥ 65 years						
1 (low porportion)	16,416	536	**1.00**	26,185	656	**1.00**
2	18,367	742	**1.28** (1.12-1.46)	27,923	827	**1.31** (1.18 - 1.45)
3	12,600	529	**1.40** (1.21-1.62)	19,035	636	**1.52** (1.36 - 1.69)
4	10,476	422	**1.40** (1.21-1.62)	15,130	480	**1.53** (1.36 - 1.72)
5 (high porportion)	5,861	232	**1.39** (1.17-1.65)	8,704	261	**1.49** (1.29 - 1.72)

P-values for linear trend: 15-64 years - Male < 0.000 Female < 0.000
≥ 65 years - Male < 0.000 Female < 0.000

The above measurement was applied to the population group with 4 or less years at death. The rates were adjusted for sex. The ratio rates for the 2nd to 5th quintiles are respectively 1.23, 1.34, 1.33, 1.72. The P-value for linear trend is significant (< 0.000).

A further investigation has shown that differentials present in all cause of death analyses are due to differences regarding to cardiovascular diseases, respiratory diseases, infectious diseases and external causes. Cardiovascular diseases and respiratory diseases are briefly presented in this section.

Cardiovascular diseases (males and females)

Table 5-8 shows population, deaths, and MR ratios of mortality due to cardiovascular diseases. The magnitude of difference in mortality due to cardiovascular disease is wider for females (15–64 years at death).

Table 5-8 Population, deaths, cardiovascular disease mortality rate ratio according to low-educated head of the household (quintiles). Male, female, 15-64 and 65 and over years at death. Belo Horizonte (1994)

Quintile	Male			Female		
	Pop.	deaths	MR ratios (95% CI)	Pop.	deaths	MR ratios (95% CI)
15-64 years						
1 (low proportion)	102,269	103	**1.00**	131,711	42	**1.00**
2	158,456	226	**1.65** (1.26-2.15)	183,993	140	**2.62** (1.86-3.71)
3	143,007	195	**1.74** (1.32-2.29)	158,308	110	**2.65** (1.86-3.78)
4	144,360	220	**2.12** (1.62-2.77)	154,168	128	**3.41** (2.41-4.83)
5 (high proportion)	96,333	126	**1.99** (1.48-2.66)	101,573	86	**3.73** (2.58-5.39)
≥ 65 years						
1 (low porportion)	16,416	221	**1.00**	26,185	283	**1.00**
2	18,367	301	**1.27** (1.06-1.53)	27,923	367	**1.36** (1.13-1.64)
3	12,600	215	**1.39** (1.15-1.69)	19,035	291	**1.61** (1.32-1.96)
4	10,476	190	**1.54** (1.26-1.88)	15,130	225	**1.64** (1.35-2.01)
5 (high porportion)	5,861	111	**1.62** (1.28-2.04)	8,704	135	**1.78** (1.41-2.25)

P-values for linear trend: 15-64 years - Male < 0.000 Female < 0.000
≥ 65 years - Male < 0.000 Female < 0.000

Table 5-8 suggests that cardiovascular diseases have responsible for an excess of deaths for males and females at an early period of adult life. The uneven distribution of mortality persists for elderly groups, but it is smoother. Among all specific causes of death studied, the cardiovascular diseases present the wider difference for women in the group of 15–64 years.

Respiratory diseases (males and females)

For males, there is not a clear trend present (Table 5-9). There is a clear difference between baseline and the other quintiles, but from 2nd to 5th quintiles the differences are not significant. The trend may be present as consequence of a possible non-linear distribution of the function.

Table 5-9 Population, deaths, respiratory disease Mortality Rate ratio comparing planning units according to the proportion of low-educated head of the household (quintiles). Male, female, all ages. Belo Horizonte (1994)

Quintile	Male			Female		
	pop.	deaths	MR ratio (95% CI)	pop.	deaths	MR ratio (95% CI)
1 (low porportion)	145,864	114	**1.00**	182,023	111	**1.00**
2	234,637	226	**1.66** (1.30-2.11)	266,431	170	**1.42** (1.10-1.83)
3	215,865	172	**1.69** (1.31-2.18)	235,013	129	**1.45** (1.11-1.90)
4	221,320	144	**1.60** (1.23-2.07)	233,880	109	**1.45** (1.10-1.91)
5 (high proportion)	155,734	96	**1.67** (1.26-2.22)	162,172	77	**1.61** (1.18-2.17)

P-values for linear trend: Male < 0.000 Female < 0.001

Two additional statistical tests were performed in order to evaluate if the relationship between outcome and exposure variable was present, and to identify a non-linear function. Firstly, the relationship between mortality due to respiratory disease and education was identified through testing the increase in MR ratios over the 5th to 95th percentile of the distribution of the proportion of low educated heads of the household. The MR ratio is 1.98, and the P-value is below 0.000. Secondly, an analysis adding a quadratic term identified a significant curvature (P-value < 0.002). Hence, the association is present and the function is non-linear.

For females, the trend is clear, suggesting a linear trend. The contrast between the sexes may suggest that socio-economic differences are responsible for the magnitude of risk ratio for females.

5.5.2 Infectious diseases

For the analysis of infectious diseases, we performed univariate analysis and multivariate analyses. The univariate analysis was performed in to two ways: 1) controlled by age and sex; 2) controlled by age and sex, under the random effects model.

The multivariate analysis was conducted in order to measure the contribution of education and each environmental variable to the health inequality in infectious diseases in Belo Horizonte. The multivariate analysis was conducted in two ways: 1) MR ratios were controlled by age, sex and the proportion of low-educated head of the household or female illiteracy, under random effect model; 2) MR ratios were controlled by age sex, the proportion of low-educated head of the household and others exposure variables, under the random effects model.

Table 5-10 shows the magnitude of association between the proportion of low-educated head of the household and mortality due to infectious diseases in the univariate and multivariate analyses. It presents exposed population, number of cases, and three scenarios for mortality rate ratios: MR ratios controlled by age and sex, mortality rate controlled by age and sex (Confidence Interval), under random effects model, and MR ratios controlled by age, sex, and physical environmental variables (Confidence Interval), under random effects model. The last column on the right shows the P-value for trend at 95%, related to the previous column.

When controlled for age, sex and environmental variables, mortality due to infectious diseases seems to be associated with low education (P-value for trend is significant). Comparing to the baseline (1st quintile), population, from areas where low education prevails (5th quintile), seems to have 87% higher risk of dying due to infectious diseases.

Table 5-10 Population at risk. Deaths due to infectious diseases. Mortality rate ratio adjusted by age and sex, MR ratio adjusted by age and sex, MR ratio adjusted by age, sex, water, sewage and rubbish collection, according to low-educated head of the household (quintiles) in Belo Horizonte - 1994

Variable	Deaths	Mortality rate ratio adjusted by age & sex	Age & sex (under random effects model)	age, sex, water, sewage and rubbish (under random effects model)	P-value
Low educated headsof the household					
1 (low proportion)	48	1.00	1.00	**1.00**	
2	114	1.72	1.65 (1.13-2.43)	**1.53** (1.05-2.21)	
3	123	2.17	2.10 (1.43-3.08)	**1.72** (1.10-2.69)	0.05
4	126	2.30	2.22 (1.52-3.24)	**1.78** (1.12-2.81)	
5 (high porportion)	109	2.85	2.69 (1.82-3.97)	**1.87** (1.13-3.11)	

Figure 5-5 shows the association between mortality rates due to infectious diseases (adjusted by age, sex and under random effects model) and selected exposure variables. As explained before, the plot at error bar type graphics indicates the mortality rate ratio. The connected lines mark the confidence interval at 95%. *The planning unit*s are grouped into quintiles. For comparison purposes, the first quintile represents the baseline.

Figure 5-5 summarises the univariate analysis. All exposure variables studied seem to be associated with its correspondent MR ratio. However, the confidence interval (CI) of the second quintile of two variables (water and rubbish collection) encompasses zero, suggesting that the found results could have been due to chance.

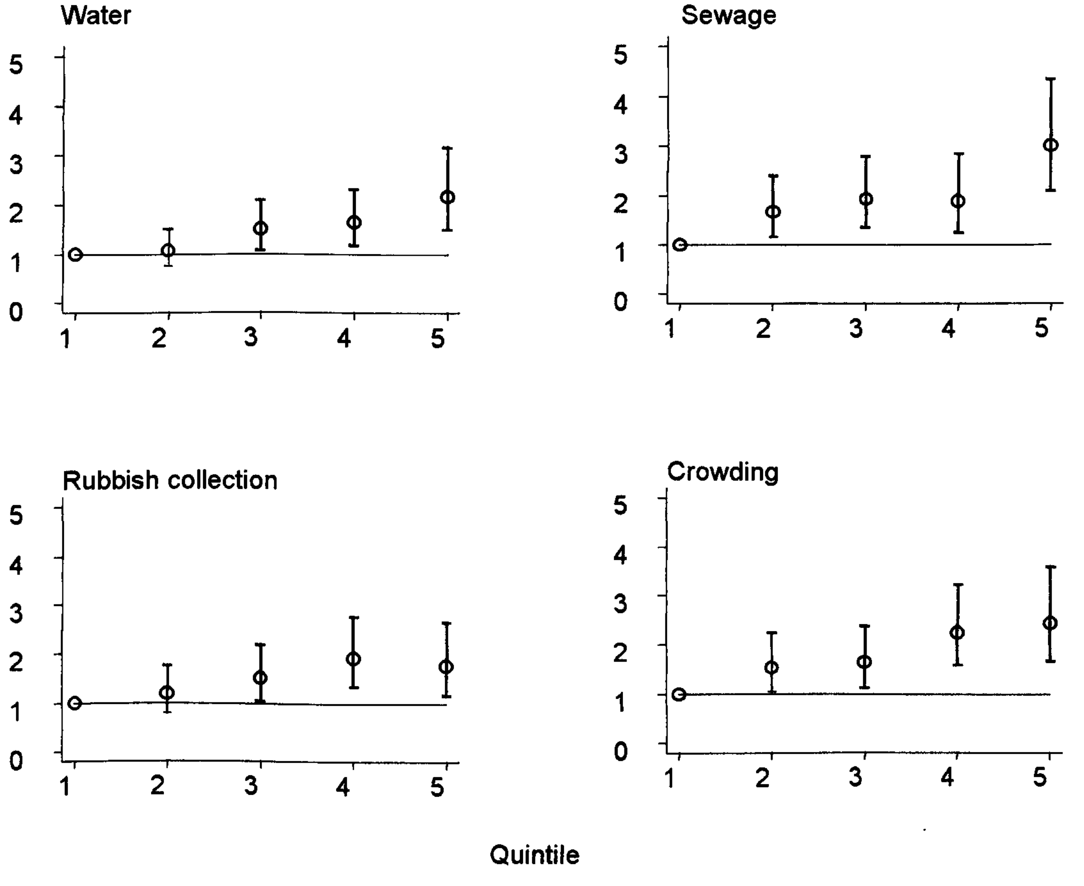

Figure 5-5 MR ratios due to infectious disease by selected exposure variables. N = 520 (for each graphic)

Table 5-11 follows the same pattern of the previous one. The last columns referred subsequently to a) mortality rates controlled by age, sex and physical environmental variables (Confidence Interval), b) P-value for trend. When adjusted by low education and other physical environmental variables, the rates present no significant association with physical environmental variables (water, sewage and rubbish collection accesses).

Table 5-11 Population at risk. Deaths due to infectious diseases. Mortality rate ratio adjusted by age and sex, MR ratio adjusted by age and sex, MR ratio adjusted by age, sex and other physical environmental variables according to access to selected environmental variables (quintiles) in Belo Horizonte - 1994

Quintiles (access)	Population	Deaths	Mortality rate ratio adjusted by: age & sex	age, sex & low-educated (under random effects model)	age, sex, low-educated & other environ. variables (under random effects model)	P value
Water access						
1(high)	478,564	86	1.00	1.00	**1.00**	0.42
2	503,171	103	1.05	1.06 (0.77-1.46)	**0.84** (0.55-1.29)	
3	483,707	136	1.53	1.31 (0.97-1.78)	**1.13** (0.75-1.70)	
4	408,749	120	1.69	1.42 (1.03-1.96)	**1.23** (0.77-1.97)	
5(low)	178,748	75	2.34	1.75 (1.19-2.60)	**1.34** (0.77-2.33)	
Sewage access						
1(high)	361,966	52	1.00	1.00	**1.00**	0.08
2	539,596	125	1.68	1.39 (0.96-2.02)	**1.53** (0.93-2.52)	
3	531,711	139	1.94	1.47 (0.99-2.20)	**1.36** (0.81-2.29)	
4	263,829	63	1.88	1.44 (0.91-2.29)	**1.21** (0.65-2.29)	
5(low)	355,837	141	3.05	2.17 (1.40-3.35)	**1.79** (0.95-3.36)	
Rubbish collection access						
1(high)	463,395	89	1.00	1.00	**1.00**	0.57
2	373,244	86	1.27	0.97 (0.65-1.44)	**0.93** (0.65-1.33)	
3	549,330	142	1.57	1.05 (0.70-1.57)	**0.88** (0.61-1.27)	
4	436,288	134	1.88	1.22 (0.79-1.88)	**0.95** (0.65-1.39)	
5(low)	230,682	69	1.85	1.00 (0.60-1.68)	**0.80** (0.51-1.27)	

Table 5-12 analyses the possible association between crowding and mortality due to infectious diseases. It basically follows the same pattern as the previous one. As explained in the Methods Chapter, female illiteracy replaced the proportion of low-educated head of the household as a proxy to socio-economic status because the latter is highly correlated to crowding, *as showed in t*able 5-2. When adjusted by female illiteracy and other physical environmental variables, the rates present no significant association with crowding.

Table 5-12 Population at risk. Deaths due to infectious diseases. Mortality rate ratio adjusted by age and sex, MR ratio adjusted by age, sex and female illiteracy, MR ratio adjusted by age, sex and other physical environmental variables, according to crowding (quintiles) in Belo Horizonte - 1994

Crowding[1]	Popul.	Deaths	Mortality rate ratio adjusted by age & sex	age, sex & female illiteracy[2] (under random effects model)	age, sex, female illiteracy[2], water, sewage & rubbish (under random effects model)	P value
1 (not crowded)	369,724	59	1.00	1.00	**1.00**	
2	411,862	95	1.58	1.47 (0.96-2.26)	**1.36** (0.90-2.06)	
3	453,264	106	1.69	1.51 (0.91-2.52)	**1.45** (088-2.39)	0.59
4	540,186	165	2.30	1.77 (0.99-3.19)	**1.74** (0.95-3.21)	
5 (crowded)	277,903	95	2.56	1.71 (0.81-3.64)	**1.62** (0.78-3.35)	

[1] person/rooms
[2] percentage of illiterate women (15-49 years old)

5.5.3 Diarrhoea, pneumonia and malnutrition (under 5)

This section presents univariate and multivariate analyses of the association between specific adjusted mortality rates and socio-economic and physical environmental variables. The mortality rates encompass combined illness of diarrhoea, pneumonia and malnutrition for children (0-4 years old at death).

Figure 5-6 summarises the univariate analysis performed for deaths due to combined illnesses of diarrhoea, pneumonia and malnutrition. The planning units are grouped in quintiles. The rates are adjusted for sex under random effect model. All the variables but female as head of the household seem to be associated with higher mortality. However, only access to sewage shows significant P-values for all quintiles.

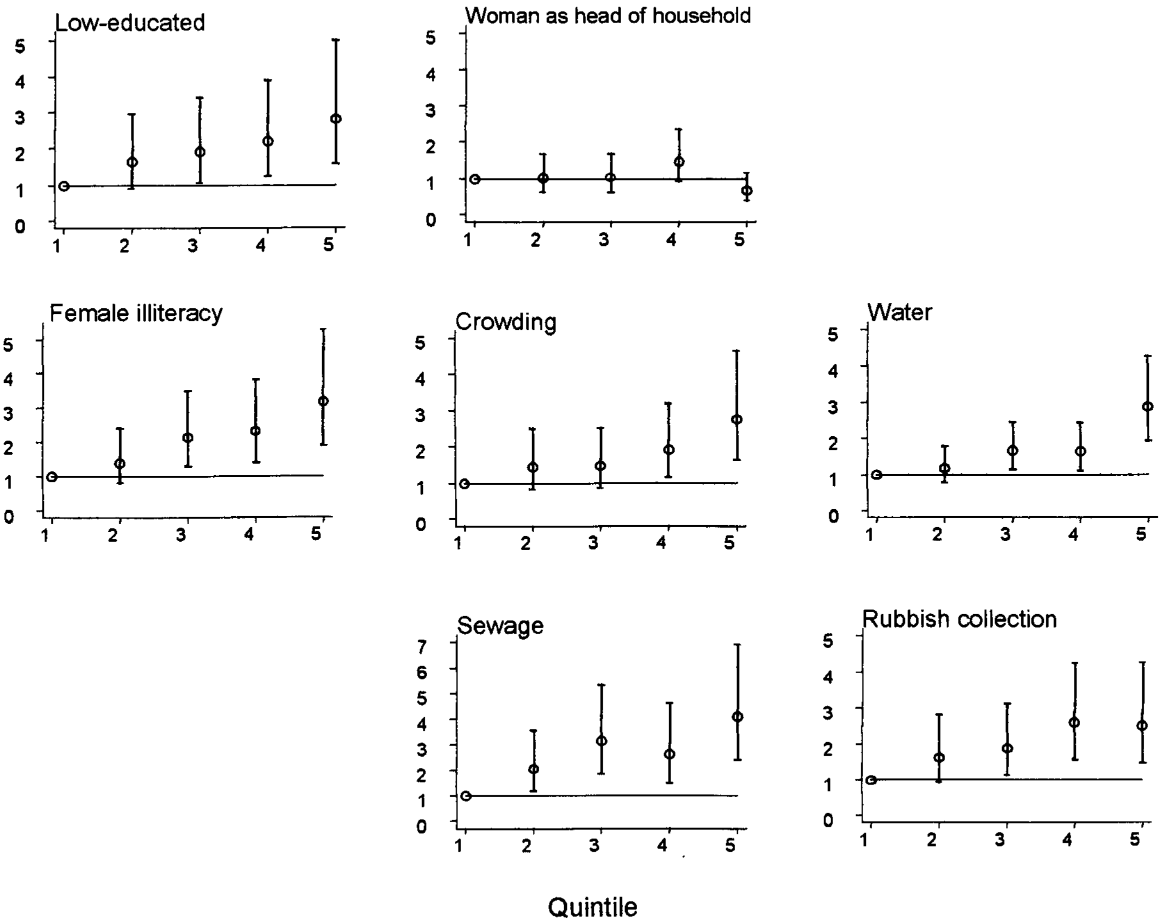

Figure 5-6 MR ratios due to diarrhoea, pneumonia and malnutrition by selected causes (0-4 years old at death). N = 362 (for each graphic)

Table 5-13 summarises the results of the multivariate analysis. The variable "female as head of the household" was not related to the mortality in the univariate analysis, nor did it have any effect in changing point estimates in multivariate models. Therefore it was not included in the final statistical model. Crowding was not controlled by low education because both are highly correlated.

Under random effect models and controlled by low education, all physical environmental variables seem to be associated with mortality. However when each variable is controlled by other variables, the associations disappear, suggesting that correlation between variables might be affecting the results.

Table 5-13 Populations at risk (0-4 years old). Deaths due to diarrhoea, pneumonia and malnutrition (0-4 years old). Mortality rate ratio adjusted by sex, MR ratio adjusted by sex and low-educated head of the household, MR ratio adjusted by sex and other variables according to selected variables (quintiles) in Belo Horizonte - 1994

Variable	Population	Deaths	Mortality rate ratio adjusted by age & sex	age, sex & low-educated (under random effects model)	age, sex, low-educated & other variables (under random effects model)	P value
Low-educated head of the household						
1 (low proportion)	17,690	17	1.00	1.00*	**1.00**	
2	38,875	64	1.73	1.64 (0.91-2.97)	**0.99** (0.55-1.81)	
3	41,145	80	2.05	1.91 (1.06-3.43)	**0.78** (0.40-1.55)	0.55
4	45,284	97	2.26	2.21 (1.25-3.91)	**0.87** (0.43-1.76)	
5 (high proportion)	35,941	104	3.05	2.83 (1.59-5.02)	**0.76** (0.35-1.70)	
Female illiteracy						
1(high)	26,857	27	1.00	1.00	**1.00**	
2	29,429	42	1.43	1.37 (0.75-2.49)	**0.88** (0.48-1.63)	
3	50,411	104	2.07	2.08 (1.15-3.76)	**0.99** (0.51-1.92)	0.10
4	43,214	95	2.20	2.46 (1.25-4.87)	**1.14** (0.52-2.53)	
5(low)	29,024	94	3.25	3.58 (1.66-7.74)	**1.37** (0.51-3.65)	
Crowding						
1 (not crowded)	20,631	23	1.00	1.00**	**1.00*****	
2	32,080	53	1.49	1.45 (0.83-2.51)	**0. 63** (0.35-1.19)	
3	40,161	69	1.56	1.48 (0.86-2.53)	**0.50** (0.25-1.01)	0.63
4	53,981	115	1.93	1.92 (1.16-3.20)	**0.52** (0:25-1.12)	
5 (crowded)	32,082	102	2.88	2.76 (1.65-4.66)	**0.66** (0.28-1.54)	
Water access						
1(high)	36,830	48	1.00	1.00	**1.00**	
2	37,804	57	1.15	1.17 (0.78-1.76)	**0.80** (0.45-1.43)	
3	42,637	91	1.64	1.51 (1.05-2.19)	**0.88** (0.53-1.49)	0.73
4	40,443	85	1.61	1.44 (0.98-2.13)	**0.77** (0.41-1.45)	
5(low)	21,221	81	2.93	2.50 (1.62-3.84)	**1.24** (0.58-2.66)	
Sewage access						
1(high)	24,165	18	1.00	1.00	**1.00**	
2	41,582	64	2.08	1.97 (1.103.51)	**2.23** (1.02-4.86)	
3	48,510	112	3.13	3.09 (1.71-5.58)	**3.05** (1.39-6.66)	0.10
4	26,284	50	2.57	2.43 (1.28-4.61)	**2.42** (1.01-5.81)	
5(low)	38,394	118	4.16	3.64 (1.96-6.75)	**3.27** (1.35-7.97)	
Rubbish collection access						
1(high)	29,126	31	1.00	1.00	**1.00**	
2	29,016	50	1.63	1.54 (0.86-2.73)	**1.47** (0.83-2.58)	
3	49,887	98	1.86	1.65 (0.93-2.94)	**1.35** (0.75-2.43)	0.82
4	44,825	115	2.43	2.15 (1.18-3.93)	**1.50** (0.83-2.70)	
5(low)	26,081	68	2.47	1.84 (0.95-3.60)	**1.26** (0.67-2.39)	

* MR ratios for the proportion of low-educated head of the household obtained under random effects model. Thereby they differ from those in previous column.
** MR ratios for crowding obtained under random effects model. Thereby they differ from those in previous column.
*** For crowding, the proportion of low-educated head of the household was not included in the model.

5.5.4 External causes

Figure 5-7 summarises the univariate analysis performed for the measurement of the association between adjusted mortality rates (external causes) and selected exposure variables. The spots indicate SMR of 75 planning units. Random effect Poisson regression model was used to perform the analysis.

The associations between the proportion of low-educated head of the household, female illiteracy, crowding and poor illumination and mortality rates are positive. The associations between main roads and police response, and mortality rates are negative. The planning unit Garças/Braúnas appears as an outlier[41] in all 6 graphics. In 1994, Garças/Braúnas presented small population (2,615) and 4 deaths due to external causes (3 homicides and 1 MVTA). Therefore is possible that the values are consequence of the small denominator and small numerator of the rates.

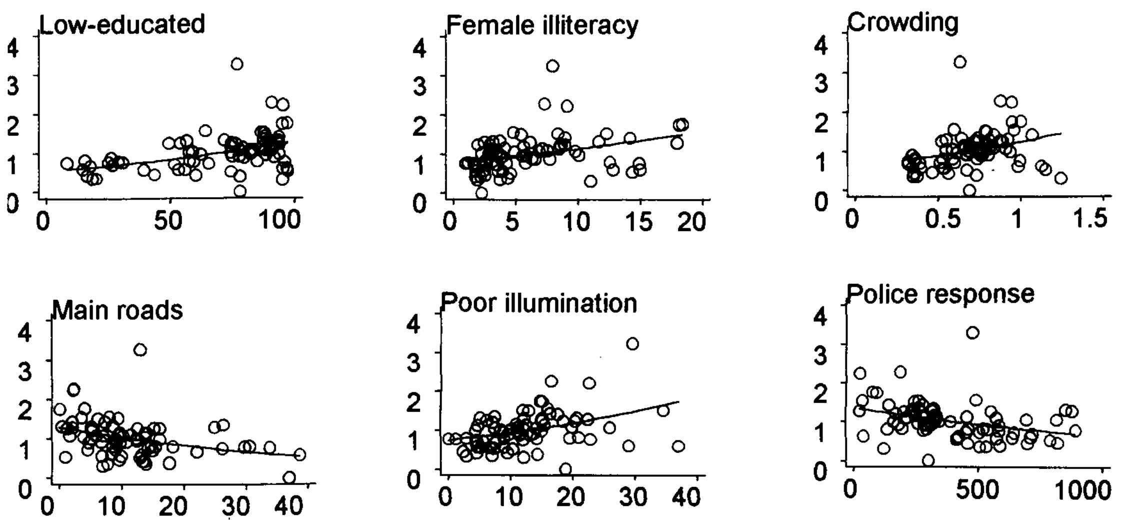

Figure 5-7 The association between mortality rate ratios (external causes) and selected explanatory variables, under random effects Poisson regression model. N = 970 (for each graphic)

Table 5-14 summarises the multivariate strategy of analysis of deaths due to external causes.

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[41] An observation that shows a markedly deviation from the other values within the diagram.

Table 5-14 Population at risk. Deaths due to external causes. Mortality rate ratio adjusted by sex, MR ratio adjusted by sex and low-educated head of the household, MR ratio adjusted by sex and other variables according to selected exposure variables (quintiles) in Belo Horizonte – 1994

Variable	Population	Deaths	Mortality rate ratio adjusted by			P value
			age & sex	age, sex & low-educated (under random effects model)	age, sex, low-educated & other variables (under random effects model)	
Low-educated head of the household						
1 (low proportion)	327,887	107	1.00	1.00*	**1.00**	
2	501,068	214	1.39	1.39 (1.10-1.75)	**1.37** (1.06-1.78)	
3	450,878	212	1.58	1.58 (1.25-2.00)	**1.46** (1.06-2.00)	0.07
4	455,200	271	2.05	2.04 (1.63-2.57)	**1.75** (1.23-2.50)	
5 (high proportion)	317,906	166	1.87	1.87 (1.46-2.40)	**1.41** (0.88-2.25)	
Illiterate females						
1 (low proportion)	443,187	163	1.00	1.00	**1.00**	
2	373,148	169	1.30	1.11 (0.87-1.42)	**1.08** (0.82-1.42)	
3	563,250	264	1.38	1.05 (0.81-1.36)	**1.04** (0.75-1.43)	0.53
4	428,639	243	1.73	1.17 (0.86-1.61)	**0.99** (0.67-1.45)	
5 (high proportion)	244,715	131	1.71	1.25 (0.85-1.86)	**0.85** (0.52-1.40)	
Crowding (person/room)						
1 (not crowded)	369,724	115	1.00	1.00**	**1.00*** **	
2	411,862	198	1.62	1.62 (1.28-2.06)	**1.54** (1.17-2.04)	
3	453,264	203	1.55	1.55 (1.23-1.97)	**1.44** (1.03-2.01)	0.03
4	540,186	296	1.97	1.97 (1.57-2.46)	**1.74** (1.15-2.66)	
5 (crowded)	277,903	158	2.13	2.14 (1.67-2.75)	**1.95** (1.13-3.38)	
Percentage of main roads						
1(low)	291,872	175	1.00	1.00	**1.00**	
2	495,476	235	0.76	0.80 (0.65-0.97)	**0.81** (0.63-1.03)	
3	540,880	250	0.74	0.81 (0.66-1.00)	**0.79** (0.62-1.01)	0.34
4	415,251	165	0.61	0.78 (0.62-0.98)	**0.80** (0.62-1.05)	
5(high)	309,460	145	0.71	0.92 (0.73-1.16)	**0.92** (0.70-1.21)	
Percentage of poor public illuminated roads						
1(high)	501,294	197	1.00	1.00	**1.00**	
2	413,894	172	1.11	0.93 (0.75-1.16)	**0.89** (0.68-1.17)	
3	547,591	277	1.39	1.05 (0.85-1.30)	**1.02** (0.77-1.35)	0.09
4	422,247	236	1.59	1.19 (0.95-1.50)	**1.11** (0.83-1.49)	
5(low)	167,913	88	1.52	1.14 (0.85-1.55)	**1.12** (0.80-1.57)	
Police response						
1(fast)	345,956	193	1.00	1.00	**1.00**	
2	427,706	235	0.95	0.85 (0.65-1.10)	**0.86** (0.65-1.15)	
3	461,576	225	0.82	0.79 (0.59-1.06)	**0.80** (0.57-1.11)	0.45
4	393,204	156	0.66	0.72 (0.52-1.01)	**0.74** (0.53-1.04)	
5(slow)	424,497	161	0.60	0.76 (0.53-1.08)	**0.73** (0.50-1.06)	

* MR ratios for the proportion of low-educated head of the household obtained under random effects model. Thereby they differ from those in previous column.

** MR ratios for crowding obtained under random effects model. Thereby they differ from those in previous column.

*** For crowding, the proportion of low-educated head of the household was not included in the model.

Table 5-14 presents population at risk, deaths, and adjusted rates under three degrees of control: age and sex, socio-economic proxy and socio-economic and physical environmental variables. The subsequent model encompasses the variables controlled by the previous model. The exceptions are low education and crowding. Those variables are highly correlated to each other. Therefore they could not be together in the same multivariate model. The percentage of illiterate females was included in the model because it is usually associated with children's accident, which is part of the external cause of death.

In Table 5-14, after being adjusted by all other variables, crowding remains significant (p=0.03, P-value for trend). Low education presents an elevation from the 2nd to 5th quintile (p=0.02, heterogeneity test).

As Figure 5-7 indicated before, the negative association between main roads and police response, and the MR ratio was still present in the multivariate model (Table 5-14), but they were not statistically significant.

5.5.5 Homicide

Figure 5-8 summarises the univariate analysis performed for measurement of the association between adjusted mortality rates (homicides) and selected exposure variables (low education, crowding, poor public illumination and police response). The spots indicate SMR of 75 planning units. We used a random effect Poisson regression model to perform the analysis. The outlier planning unit Garças/Braúnas was excluded from the graphic because it produced an extreme value (9.98) affecting decisively the least-squares fitting of the model.

Figure 5-8 shows that low-education, crowding and poor public illumination seems to have positive correlation with homicides. A negative correlation seems to occur between police response and homicides.

In all the graphics, three planning units are placed far from the predictor line because their higher SMRs. Prado Lopes, Jardim Montanhes and Morro das Pedras are respectively 5.58, 5.08 and 4.42 SMR. In the same order, homicide frequencies are 6, 9 and 10. Prado Lopes and Morro das Pedras are shantytowns (favelas) with a great population concentration (9,995 and 21,155). Jardim Montanhes is a poor and heterogeneous planning unit, mixing favela with regular settlements.

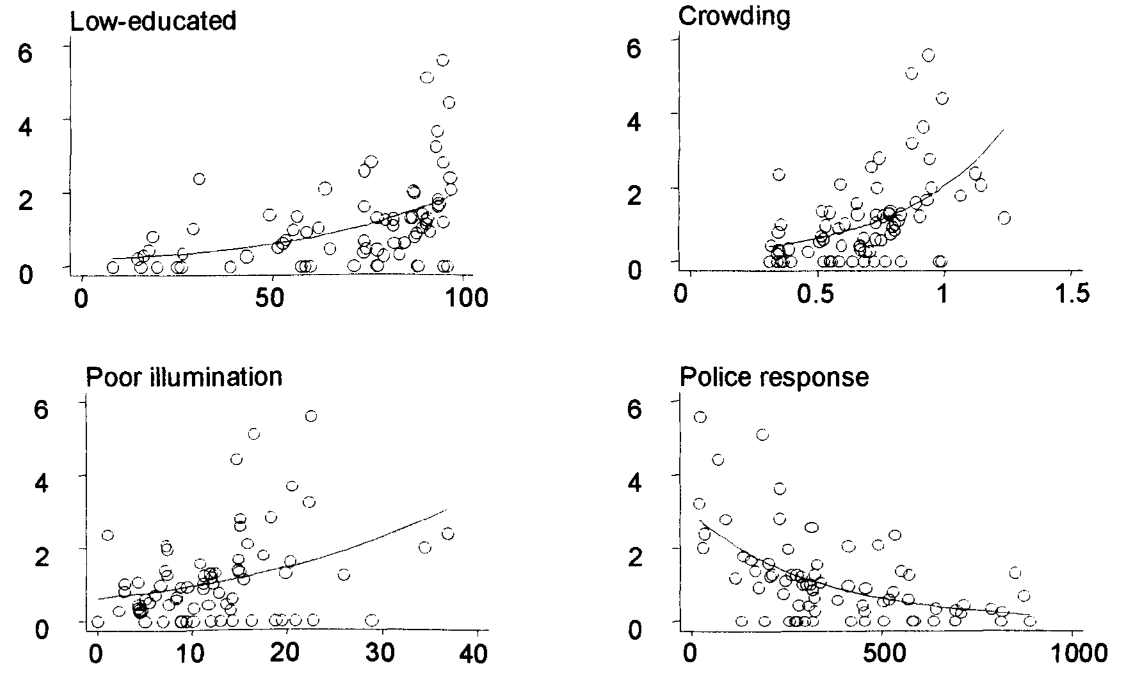

Figure 5-8 The association between adjusted mortality rates (homicide) and selected explanatory variables, under random effects Poisson regression model. N = 232 (for each graphic)

Table 5-15 summarises the multivariate analyses performed for the study of the association between homicide and selected variables. When controlled by other variables, low education and crowding do not present statistically significant associations with homicides.

Poor public illumination seems to be to compatible with linear trend. However, it does not indicate any difference between the baseline and the 2nd quintile.

When controlled for other variables, the relationship between police response and homicide is pictured as a downward trend, suggesting that access to police is associated with homicide. This issue is better explored in the Discussion Chapter.

Table 5-15 Population at risk. Deaths due to homicide. Mortality rate ratio adjusted by sex, MR ratio adjusted by sex and low-educated head of the house, MR ratio adjusted by sex and other variables according to selected exposure variables (quintiles) in Belo Horizonte – 1994

Variable	Population	Deaths	Mortality rate ratio adjusted by: age & sex	age, sex & low educated (under random effects model)	age, sex, low-educated & other variables (under random effects model)	P value
Low-educated head of the household						
1 (low proportion)	327,887	17	1.00	1.00*	**1.00**	0.49
2	501,068	37	1.37	1.33 (0.69-2.59)	**1.12** (0.61-2.07)	
3	450,878	53	2.17	2.19 (1.16-4.16)	**1.54** (0.80-2.98)	
4	455,200	56	2.27	2.32 (1.23-4.36)	**1.30** (0.65-2.61)	
5 (high proportion)	317,906	69	4.15	4.33 (2.32-8.10)	**1.24** (0.58-2.62)	
Crowding (person/room)						
1 (not crowded)	369,724	17	1.00	1.00**	**1.00*****	0.29
2	411,862	38	1.93	1.95 (1.05-3.62)	**1.44** (0.75-2.76)	
3	453,264	44	2.01	1.98 (1.07-3.64)	**1.37** (0.69-2.74)	
4	540,186	64	2.48	2.52 (1.40-4.51)	**1.49** (0.69-3.21)	
5 (crowded)	277,903	69	5.38	5.56 (3.10-9.97)	**1.98** (0.86-4.55)	
Percentage of poor public illuminated roads						
1 (high)	501,294	30	1.00	1.00	**1.00**	0.03
2	413,894	38	1.51	1.09 (0.60-1.98)	**0.99** (0.58-1.71)	
3	547,591	59	1.77	1.26 (0.70-2.27)	**1.50** (0.86-2.60)	
4	422,247	70	2.75	1.78 (0.97-3.24)	**1.72** (1.00-2.96)	
5 (low)	167,913	35	3.50	1.94 (0.97-3.88)	**1.97** (1.06-3.68)	
Police response						
1 (fast)	345,956	79	1.00	1.00	**1.00**	0.02
2	427,706	48	0.48	0.49 (0.28-0.86)	**0.44** (0.26-0.76)	
3	461,576	49	0.45	0.46 (0.25-0.87)	**0.48** (0.26-0.88)	
4	393,204	38	0.42	0.50 (0.25-1.02)	**0.60** (0.32-1.14)	
5 (slow)	424,497	18	0.18	0.25 (0.11-0.56)	**0.27** (0.13-0.57)	

* MR ratios for the proportion of low-educated head of the household obtained under random effects model. Thereby they differ from those in previous column.
** MR ratios for crowding obtained under random effects model. Thereby they differ from those in previous column.
*** For crowding, the proportion of low-educated head of the household was not included in the model.

5.5.6 Motor vehicle traffic accidents (MVTA)

Figure 5-9 summarises the univariate analysis performed for the study of the association of MVTA and selected exposure variables. The exposure variables are: the proportion of low educated heads of the household, percentage of poor public illuminated roads, percentage of main roads, and police response.

Figure 5-9 indicates that low education and poor public illumination seem to be related to MVTA. However the scatter seem to be overdispersed around the axis.

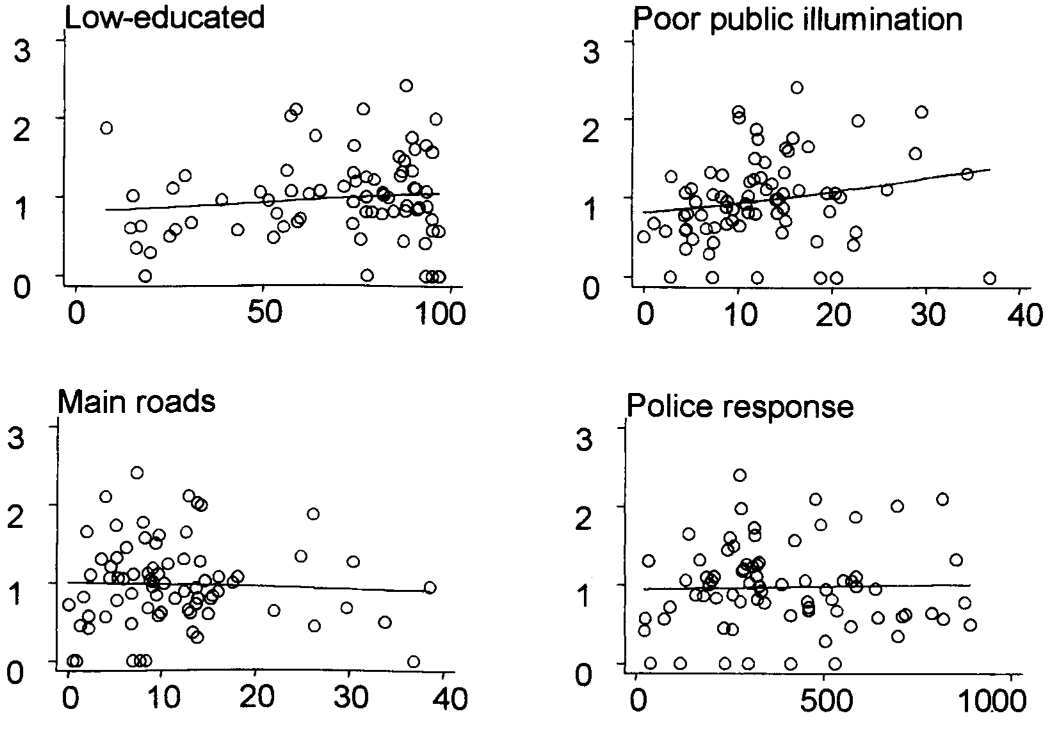

Figure 5-9 The association between adjusted mortality rate ratios (MVTA) and selected explanatory variables, under random effects Poisson regression model. N = 378 (for each graphic)

Table 5-16 shows the multivariate analysis performed for the study of the association between MVTA and selected exposure variables. When controlled by other variables, poor public illumination is compatible with the linear trend.

Table 5-16 Population at risk. Deaths due to MVTA. Mortality rate ratio adjusted by sex, MR ratio adjusted by sex and low-educated head of the household, MR ratio adjusted by sex and other variables according to selected exposure variables (quintiles) in Belo Horizonte – 1994

Variable	Population	Deaths	Mortality rate ratio adjusted by age & sex	age, sex & low-educated (under random effects model)	age, sex, low-educated & other variables (under random effects model)	P value
Low educated headsof the household						
1 (low proportion)	327,887	42	1.00	1.00*	**1.00**	
2	501,068	93	1.55	1.55 (1.07-2.23)	**1.44** (0.96-2.16)	
3	450,878	83	1.60	1.60 (1.10-2.31)	**1.34** (0.83-2.16)	0.47
4	455,200	112	2.19	2.19 (1.55-3.13)	**1.57** (0.92-2.67)	
5 (high proportion)	317,906	48	1.40	1.40 (0.92-2.12)	**1.06** (0.55-2.09)	
Percentage of main roads						
1 (high)	291,872	56	1.00	1.00	**1.00**	
2	495,476	91	0.92	0.92 (0.65-1.28)	**1.02** (0.71-1.47)	
3	540,880	108	0.99	1.00 (0.71-1.40)	**0.96** (0.67-1.39)	0.54
4	415,251	70	0.80	0.95 (0.65-1.38)	**0.94** (0.63-1.40)	
5 (low)	309,460	53	0.81	1.00 (0.67-1.49)	**0.90** (0.58-1.40)	
Percentage of poor public illuminated roads						
1 (high)	501,294	197	1.00	1.00	**1.00**	
2	413,894	172	1.25	1.15 (0.81-1.63)	**1.16** (0.81-1.66)	
3	547,591	277	1.70	1.39 (0.99-1.96)	**1.35** (0.93-1.95)	0.03
4	422,247	236	1.78	1.60 (1.11-2.31)	**1.59** (1.07-2.36)	
5 (low)	167,913	88	1.32	1.34 (0.80-2.24)	**1.26** (0.75-2.14)	
Police response						
1 (fast)	345,956	56	1.00	1.00	**1.00**	
2	427,706	102	1.42	1.15 (0.75-1.79)	**1.16** (0.70-1.91)	
3	461,576	89	1.12	0.95 (0.58-1.56)	**1.00** (0.58-1.74)	0.64
4	393,204	60	0.86	0.84 (0.48-1.45)	**0.92** (0.52-1.63)	
5 (slow)	424,497	71	0.90	1.03 (0.58-1.82)	**1.07** (0.57-2.01)	

* MR ratios for the percentage of low-educated head of the family obtained under random effects model. Thereby they differ from those in previous column.

5.6 Conclusions

In general, the univariate analysis indicates associations between physical environmental variables and the mortality rate ratios. However, MVTA seems associated with only one environmental variable: poor public illumination.

The proportion of low-educated head of the household is statistically significantly correlated with mortality rate ratios related to all cause of death, infectious diseases, external causes, and homicide, and combined illnesses of diarrhoea, pneumonia and malnutrition. The MR ratio differentials between the areas are also marked.

The association between the proportion of low-educated head of the household and all causes of death is statistically significant, and the differentials are markedly high for all age groups and sexes. Areas with high proportion of low-educated head of the household present the following statistically significant MR ratios: 1.72 for children under 5 years, 1.59 for males between 15 and 64 years, 2.46 for females between 15 and 64 years, 1.39 for males with 65 and over years, and 1.49 for females with 65 and over years. These differentials are strongly affected by the differences in rate ratios related to cardiovascular diseases for adults. Areas with high proportion of low-educated head of the household present the following statistically significant cardiovascular MR ratios: 1.99 for males between 15 and 64 years, 3.73 for females between 15 and 64 years, 1.62 for males with 65 and over years, and 1.78 for females with 65 and over years.

Environmental variables also presented strongly associated with mortality, presenting marked differentials between affluent and deprived areas. Deaths due to combined illnesses of diarrhoea, pneumonia and malnutrition, and homicides show greater differences between areas. Mortality rate ratios due to diarrhoea, pneumonia and malnutrition are strongly associated with women illiteracy, and lack of access to sewage. Population living in the most deprived areas present 3.58 (CI 11.66-7.74) greater chance to die due to diarrhoea than the population of the baseline, pneumonia and malnutrition, and 3.64 (CI 1.96-6.75) in relation to MVTA. Homicide presents a very high MR ratios differentials in relation to crowding. Population living in areas with higher concentration of crowded households has 5.56 (CI 3.10-9.97) greater chances to be killed than the population of the baseline[42].

In the second step of the multivariate analysis, the effect of each variable is measured controlling for all other variables. Deaths due to external causes remain statistically significantly associated with overcrowded households, presenting the MR ratio equals to 1.95 in the 5th quintile. Population living in areas with the highest proportion of crowded household has 1.95 (P-value for trend: 0.03) greater chance to die due to external causes than those from the baseline. Poor public illumination is associated with homicide and MVTA. Population living in areas that concentrate the greatest percentage of poor illuminated streets

[42] As defined in Methods Chapter, baseline refers to 1st quintile, i.e., the areas with the most "favourable" condition.

has 1.95 (P-value for trend 0.03) and 1.26 (P-value for trend: 0.03) greater chance to die respectively due to homicide and MVTA. Mortality due to combined illness of diarrhoea, pneumonia and malnutrition and is remarkably high in areas with low access to public sewage, presenting a MR ratio equals to 3.27 in relation to the baseline ($p=0.05$, heterogeneity test).

Descriptive and analytical techniques suggest a polarisation in mortality between the affluent and the poorer areas: baseline versus 5th quintile. The maps indicate that central areas and Pampulha, and the favelas represent more precisely these poles.

Mapping the data shows that central areas and Pampulha present favourable socio-economic and environmental characteristics and also the indicators predictive of lowest mortality. The maps indicate that favelas around the central area, northeaster areas and areas in the extreme south present the less favourable indicators for both socio-economic conditions and physical environment. Mortality rate ratio maps show that the highest values concentrated in the 8 areas constituted by the biggest favelas of the city.

Both sets of maps (characteristics and mortality maps) suggest a polarisation between the favelas and all other areas. In general, the areas in between present indistinct patterns. That leads to further exploration of the data, comparing favelas to non-favelas areas. In this stage, as part of the objectives of the research, the favelas are compared to other areas all together. This aims to highlight the differences between the most vulnerable group and populations of the rest of the city.

Chapter 6 - Results II

6.1 Favelas

This chapter basically follows the same structure as the previous chapter. The first section describes the socio-economic and the environmental characteristics of the two planning unit sets (favela and non-favela). The second section presents the results related to the comparison of mortality in the two planning unit sets. Descriptive measurement techniques and analytical methods are the basic methods in this section.

The eight planning units constituted by the main favelas of the city are compared to remaining planning units (67). These favelas were chosen because they encompass the majority of the planning unit. They are homogeneously favela-planning units. The remaining planning units encompass some smaller favelas, but the non-favela population occupies the major part of the planning units. Therefore the planning units were classified according to the origin of the dominant population. The favelas considered in this study encompass 9.9% of the whole population and 10.2% of all deaths in 1994.

In the final stage of the multivariate analysis, the effect of the proportion of the low-educated head of the family is controlled. This allows for measuring the effect of the environmental variables over the mortality in favelas and non-favelas areas. This classification works as a proxy for physical environmental composite index in this phase of the research

6.2 Characteristics of the study area

This section gives the description of the characteristics of the planning units grouped as non-favelas (67) and favelas (8). The concepts used in the previous chapter are also valid for this one. The variables used in the previous chapter are treated here in the same way. However, differently from the previous chapter, the analysis is based on only two groups: favelas and non-favelas. Table 6-1 summarises the socio-economic and physical characteristics of the two planning unit groups.

6.2.1 Demographic characteristics

There is no significant difference in terms of the sex ratio between non-favela and favela planning units. However, in terms of population structure, non-favelas seem to have on average fewer children and more adults and aged population than the favelas. On average, non-favelas have twice the elderly people than the favelas.

6.2.2 Socio-economic characteristics

In non-favelas, the monthly income average of the head of the household is 3,7 times greater than the favelas. Educational characteristics are also unfavourable in the favelas. The proportion of low-educated head of the household is 28% higher in favelas than the non-favela planning units. The proportion of illiterate females is 2.6 times greater in favelas than non-favelas. The proportion of females as head of the household does not seem to vary between the two groups.

Table 6-1 Summary of demographic, socio-economic, physical environmental, and other characteristics in non-favelas (67 planning units) and favelas (8 planning units) in Belo Horizonte

Variables	Mean (s.d.) Non-favelas	Favelas
DEMOGRAPHIC		
0-14 years (pop.)	7,495 (5,209)	8,811 (6,134)
15-64 years (pop.)	18,634 (12,289)	15,714 (13,180)
65 and more (pop.)	1,489 (1,305)	793 (769)
SOCIO-ECONOMIC		
Monthly income (US$)	463.7 (462.6)	125.9 (40.1)
Low-educated head of the household (%)	66.2 (25.6)	94.0 (3.4)
Female illiteracy (%)	5.2 (3.4)	13.9 (4.1)
Female as head of the household (%)	23.3 (6.7)	26.9 (4.7)
PHYSICAL ENVIRONMENT		
Overcrowded (person/room)	0.65 (0.19)	1.00 (0.15)
Water (%)	91.6 (7.7)	78.8 (9.8)
Sewage (%)	90.3 (6.5)	80.6 (7.6)
Rubbish (%)	81.1 (20.2)	65.8 (24.0)
Great road (%)	12.4 (8.2)	3.4 (3.2)
Poor Illumination[1] (%)	12.2 (7.6)	15.4 (5.3)
OTHER		
Police response (min.)	416 (211)	142 (133)

[1] Areas illuminated by post lamps, each one with more than 40 meters of distance from the other

6.2.3 Physical environmental characteristics

Among the physical environmental variables studied, 4 out of 6 vary favourably to non-favelas. In favelas, the crowding index (person/rooms) is 52% greater in favelas than the non-favelas. The access to sanitary services is lower for favela inhabitants. On average, access to water, sewage and litter collection is respectively lower for the favelas: 11.4%, 8.5% and 13.7. The favelas present a lower percentage of motorways and primary roads than non-favelas, indicating roads less prone to MVTA. On average, the proportion of motorways and primary roads are 4.3 times greater in non-favelas than in the favelas. Poor illumination does not indicate a significant variation between the two geographical groups.

6.2.4 Other characteristics

The police response to high priority calls is 2.9 times faster in favelas than in non-favelas. In 1994, the Belo Horizonte police had free access to the favelas. Differently from Rio at that time, the drug dealers did not control the access to the favelas of Belo Horizonte.

6.3 Mortality differentials between favelas and non-favelas

This section presents the mortality analysis using descriptive and analytical techniques. That follows the same methodology adopted in the previous chapter. Initially, sex and age adjusted mortality rate are presented. Finally, Poisson regression methods are presented. Descriptive techniques are used in order to describe the mortality differentials between favelas and non-favelas. Analytical techniques are used in order to estimate the magnitude of the mortality differentials between the two geographical groups.

6.3.1 Descriptive techniques

Table 6-2 presents unadjusted, and age and sex adjusted mortality rates. The ratios are presented according to the type of planning unit: non-favelas and favelas. In general term, favelas present adjusted rates greater than non-favelas. The greatest difference occurs in the 0-4 years age group. In favelas, sex adjusted mortality rates for children (0-4 years) are 1.47 greater than in non-favelas.

Table 6-2 All cause mortality rate unadjusted and adjusted by sex and age (when appropriated), by age group in non-favelas and favelas (/10,000) in Belo Horizonte (1994

Age Group		Non-favela	Favela
all ages			
	population	1,850,389	202,550
	deaths	9,485	1,073
	rates	51.3	53.0
	Adjusted rates	**49.6**	**64.1**
0-4			
	population	155,763	23,172
	deaths	1,169	255
	rates	75.0	110.0
	Adjusted rates	**75.0**	**110.1**
15-64			
	population	1,248,465	125,713
	deaths	3,961	492
	rates	31.7	39.1
	Adjusted rates	**31.4**	**42.7**
65 +			
	population	99,749	6,348
	deaths	4,221	300
	rates	423,2	472,6
	Adjusted rates	**427,5**	**494,8**

Table 6-3 presents age and sex mortality rates due to selected causes in favelas and non-favelas. In favelas, mortality due to infectious diseases, external causes and homicide present greater adjusted rates than non-favelas. MVTA present no difference. Homicides account for the greatest differences. Favelas present a rate 2.7 greater than non-favelas.

In relation to cardiovascular and respiratory diseases, the differences between the two groups are modest. For cardiovascular diseases, non-favleas present 15.7 while favelas present 18.5. For respiratory diseases, non-favelas present 6.6 while favelas present 7.3.

Table 6-3 Selected age and sex adjusted mortality rates (/10,000) in non-favelas and favelas planning units in Belo Horizonte (1994). All ages. Both sexes.

area	population	infectious diseases		external causes		homicide		MVTA	
		deaths	**rates**	deaths	**rates**	deaths	**rates**	deaths	**rates**
non-favela	1,850,389	448	**2.4**	861	**4.4**	181	**0.9**	342	**1.8**
favela	202,550	72	**5.1**	109	**6.6**	51	**2.4**	36	**1.9**

6.3.2 Analytical techniques (Poisson regression methods approach)

This section analyses the relationship between a proxy of physical environmental variables and selected mortality risk ratios, using Poisson regression methods. The mortality due to all causes, circulatory diseases, respiratory diseases, infectious diseases and external causes is investigated. Among the external causes, homicides and MVTA are further studied. The combination of diarrhoea, pneumonia and malnutrition is studied for the 0-4 years group.

Table 6-4 summarises the analysis carried out for all selected cause of death. The mortality rates are standardised by five-year age and sex. The baseline is represented by non-favelas. The left column of the table started with "P-value" indicates the statistical test for linear trend of the mortality ratios across the strata of low education.

Table 6-4 Deaths due to selected causes. Mortality rate ratio (MR ratio) adjusted by age and sex, MR ratio adjusted by sex and the proportion of low-educated head fo the household under random effect model in non-favelas[1] and favelas[2] planning units of Belo Horizonte – 1994

Variable	Deaths	Mortality ratios adjusted by age & sex	Mortality ratios adjusted by age, sex & low-educated (under random effects model)	P-value
Disease groups (ICD)				
All-causes				
Non-favelas	9,485	1.00	**1.00**	
Favelas	1,073	1.34	**1.12** (1.00-1.26)	0.04
Circulatory diseases				
Non-favelas	3,170	1.00	**1.00**	
Favelas	225	1.22	**0.96** (0.82-1.13)	0.65
Respiratory diseases				
Non-favelas	1,250	1.00	**1.00**	
Favelas	98	1.19	**0.99** (0.78-1.25)	0.93
Infectious diseases				
Non-favelas	448	1.00	**1.00**	
Favelas	72	2.09	**1.59** (1.21-2.10)	0.00
External causes				
Non-favelas	861	1.00	**1.00**	
Favelas	109	1.55	**1.26** (1.03-1.53)	0.03
More specific causes				
MVTA				
Non-favelas	342	1.00	**1.00**	
Favelas	36	1.05	**0.85** (0.60-1.22)	0.38
Homicides				
Non-favelas	181	1.00	**1.00**	
Favelas	51	2.65	**2.05** (1.31-3.22)	0.00
Diarrhoea, pneumonia and malnutrition (<5 years old)				
Non-favelas	278	1.00	**1.00**	
Favelas	84	2.04	**1.62** (1.17-2.25)	0.00

[1] Non-favelas population is 1,850,389 (all ages) and 155,763 (under 5 years old)
[2] Favelas population is 202,550 (all ages) and 23,172 (under 5 years old)

Adverse socio-economic conditions in favelas seem to be related to higher risks of death due to cardiovascular diseases and respiratory diseases. When low education is controlled, the differences between the two groups disappear.

When controlled by low education of the head of the family, favelas present a greater risk of dying due to infectious disease and external causes. Mortality rate ratios are 1.59 and 1.26 for infectious diseases and external causes. In terms of homicide, people living in favelas are more than 2.05 times as likely to be killed than those who live elsewhere. At P-value lower than 0.00, the population living in favelas has 62% greater chance to die due to combined illness of diarrhoea, pneumonia and malnutrition (<5years old) than those who live in non-favela areas.

6.4 Conclusions

Both descriptive and analytical techniques suggests that the adverse socio-economic and environmental conditions produces an excess of death in relation to homicide, combined illnesses of diarrhoea, pneumonia and malnutrition for children under 5, external causes of death and all cause of death.

The favelas present higher mortality rates when descriptive techniques are used. In analytic techniques, when the impact of living in favelas is measured controlling by the proportion of low-educated head of the household, all tested diseases except MVTA present greater chance of death for favela populations than populations living in non-favela areas. Favelas' population present subsequently greater chance to die than non-favelas' population due to the following diseases: 1.12 (p=0.04), all cause of death; 1.59 (p=0.00), infectious diseases; 1.26 (p=0.03), external causes; 2.05 (p=0.00), homicide; and 1.62 (p=0.00), combined illness of diarrhoea, pneumonia and malnutrition (under 5 years old).

Findings from this evidence, together with the evidence that was presented in chapter 5, are debated in the following chapter. The evidence from Belo Horizonte is compared to those found in other studies carried out, especially in Brazil. Concepts used by the epidemiological transition and social exclusion theories are incorporated in the discussion.

Chapter 7 - Discussion, policy implications and recommendations

This chapter concerns the main findings of the study, referring to both Chapter 5 and Chapter 6. It describes the methodological limitations of the study design, biases, misclassification and confounding. This is followed by a discussion and comparison of the results related to each cause of death with those from the reviewed literature. Further this chapter discusses the implications of these results on models of the epidemiological transition and social exclusion in Brazil, in general, and in Belo Horizonte in particular.

In the last part of this chapter presents the main conclusion, the policy implications and recommendations. Policy implications and recommendations are presented in three levels: general, national and local.

7.1 Main findings

Data from Belo Horizonte suggests that:

- Death due to all causes, infectious diseases, external causes, homicide and combined illness of diarrhoea, pneumonia and malnutrition are significantly associated with social and environmental deprivation.
- In relation to each exposure variable, the differences between the affluent and the most deprived areas are high. Specially, the variation in the education level of the head of the family produces a marked variation in the mortality due to all causes of death across the

areas for all age groups and both sexes. Females between 15 and 44 years old present the most substantial difference.

- The multivariate analysis indicates statistically association and marked geographical differentials in relation to: the proportion of low-educated head of the family and infectious diseases; access to sewage and combined illness of diarrhoea, pneumonia and malnutrition; crowding and external causes of death; public illumination and homicide and also in relation to MVTA; police response and homicide.

- The data clearly indicates that the most vulnerable population lives in shantytown areas (the favelas). In the favelas, the environmental variables are responsible for significant excess of deaths in relation to infectious diseases, homicides and combined illness of diarrhoea, pneumonia and malnutrition. After controlling for social factors, the statistically significant MR ratios are respectively 1.59, 2.05 and 1.62.

- In relation to social factors, motor vehicle traffic accidents present a different pattern. They did not present a statistically significant association with social factors.

- The evidence of the association between health inequality and adverse social and environmental factors come from both descriptive techniques (including mapping) and analytical techniques.

- The study also shows that the exposure variables vary across the areas but are highly correlated to each other.

7.2 Methodological limitations

This section provides an overview of the methodological limitations of the present study. The study designs, the role of chance, bias and confounding are discussed in turn.

7.2.1 Limits of the study design

The main limitation in ecological studies is the ecological fallacy or cross-level bias even when the target level of inference is an ecological one (MORGENSTERN, 1982). In a multiple-group comparison ecological study, heterogeneity among the population of each area is the key point of ecological fallacy. In this study, the geographical areas were redefined in order to minimise the level of heterogeneity across the areas.

Missing death certificates is the main problem of this research. This is a common problem in studying developing countries, constraining the epidemiological findings and health policy recommendations. In this research, the limitations regarding to mortality data are loss of original documents, and lack or misclassification of address and underlying cause of death. Population data are more reliable, but data related to intra-urban mobility are not available. Few environmental variables were available in the adequate spatial resolution. That limited the study of homicides and specially MVTA.

Using data for one year aggravated temporal ambiguity usually present in ecological studies because the induction and the latent periods between the exposure and the death could not be observed in the study.

Co-linearity and migration across the areas remained limitation of the study. Explanatory variables often present higher degree of co-linearity at group level than at individual level (MORGENSTERN, 1998). Intra-urban mobility was not studied, especially when the migration means changes in levels of exposure of socio-economic and physical environmental factors. In Brazil, intra-urban mobility can not be assessed through routine data.

7.2.2 The role of chance

In the present type of ecological study, problems in analysing mortality rates can occur as a consequence of three contingencies: areas sparsely populated, overdispersion and spatial auto-correlation. In the statistical analysis, these problems were partially covered.

Only planning units with 2,584 and more inhabitants were allowed in the study. Random Effect Poisson Regression approach was chosen for dealing with overdispersion. Estimated frailty variance for each death cause was observed to evaluate if the population of each geographical areas were heterogeneous for risk factors not controlled under the statistical model. After the final adjustments, the variances presented lower values, indicating substantial degree of homogeneity between the areas for unknown or unmeasured variables.

Because of the limitation of the mortality data, there was no formal allowance for spatial auto-correlation. With low overall overdispersion, auto-correlation is unlikely to be strong. In addition that, the contiguous areas are not similar in relation to the exposure variables.

7.2.3 The role of bias

In the present type of ecological study, limitations in outcome measurement are the most important source of bias. Misclassification of the underlying cause of death and address of the deceased have been discussed in the Methods Chapter.

More general concerns in relation to the classification of the areas have been raised by HERTZ-PICCIOTTO (1998). She advocates that misclassifications of area socio-economic status can be reduced if more socio-economic variables were combined in the measurement. The main limitation for her approach is related to the high degree of correlation between exposure variables. In Belo Horizonte for example, the high degree of correlation between low education (Table 4-2) with both income of the head of the family and crowding (-0.98 and 0.98, subsequently) demonstrated that a composite socio-economic index derived from available data, in this circumstance, would be redundant and "unnecessarily" complex. In this study, the proportion of low-educated head of the family (and eventually female illiteracy) was used for socio-economic status definition.

7.2.4 The role of confounding variables

Confounding variables are related to a mixing of effects between the outcome of interest, the exposure under investigation and an extraneous factor (the confounder). The confounder must be associated with both the exposure and the outcome, distorting the association measurement (HENNEKENS AND BURING, 1987).

In multiple-group ecological comparison, it is possible to control for confounders if additive confounders are considered as covariates within the regression model. This is based on the assumption that, at the individual level the effects of the exposure and the covariates must be additive on the outcome rates. Therefore the regression slope will be also linear at group level (MORGENSTERN, 1998).

In the final stage random effect Poisson regression model was used for treating all measured potentially confounding variables as covariates. Poisson regression methods also allow for more complicated models (KLEINBAUM ET AL, 1998), such as log linear model what is the case of this research. Random effect approach further allowed for unknown or unmeasured predictors Therefore, unknown and unmeasured variables, and multiplicative effects were considered within the statistical model. However, all these measures are insufficient to remove completely the effect of confounders into the analysis because of possible unmeasured interaction at individual level that distort the results at ecological level (MORGENSTERN, 1998). The following sub-section presents a peculiar confounding effect found in this research.

Confounding by indication

In the section 5.5.5 (Chapter 5), a notable result related to the downward trend between police response and homicides (Figure 5-8) was found, suggesting that homicides are directly associated with police protection. That might be consequence of confounding by indication, as proposed by MIETTINEN (1985). This means that a spurious association between the intervention with the outcome parameter is present if the perceived high risk is an indication for intervention (SALAS, 1999). In this particular case, the police are prioritising the areas with higher homicide rates. That is why the higher access to police is associated with higher homicide rates. However, the police cannot prevent the high occurrence of the outcome among the planning units. The findings suggest that further measures should be taken to tackle homicide in Belo Horizonte.

7.3 Discussion and comparison of the findings with those from the reviewed literature

Despite the urban population concentration in developing countries, most published ecological studies focusing socio-economic and environmental health inequalities remain related to developed country cities. These refer to different demographic and epidemiological patterns, with different social support structures and access to health care than those in developing country cities. As a consequence, developing country cities may demand different socio-economic and environmental indicators or different interpretations for indicators used in European and North American cities. For example, lone pensioner is an "unfavourable" component of the Jarman Index (JARMAN, 1983). However, this study and others suggest that this indicator could be interpreted in the opposite way in Brazilian cities. In a developing country city, lone pensioner often means surviving beyond the life expectancy average and being able to cope with daily expenses.

In developing country cities, intra-urban studies are constrained by lack of data of sufficient detail and spatial resolution (HERBERT AND HIJAZI, 1984). In Brazil in the last 10 years, GIS and electronic cartography techniques have been quickly absorbed by Brazilian academic and governmental institutions. The first comprehensive epidemiological intra-urban studies started to be published. They focused specially in São Paulo (CEDEC, 1996, STEPHENS ET AL, 1994, BARATA ET AL, 1998), Rio (SZWARCWALD AND CASTILHO, 1998 and SZWARCWALD ET AL, 1999), and Salvador (PAIM AND COSTA, 1993 and SILVA ET AL, 1999). The findings of this research will be compared to those from the mentioned cities. Finally, other urban studies will be also considered.

7.3.1 All causes of death

The studies carried out in Brazilian cities used different techniques for measuring inequalities and obtained contradictory results.

For São Paulo, STEPHENS ET AL (1994) used a composite socio-economic and environmental deprivation index, aggregating areas into quartiles. For all age groups, they found small differences in age adjusted mortality rates between the less favourable quartile to the most favourable one. For age group 0-4, 15-44 and 45-64, they found marked differentials.

For Rio, SZWARCWALD ET AL (1998) analysed the correlation between some income distribution indexes (Gini Index, Robin Hood Index, and 10%wealthiest / 40%poorest ratio) and adjusted mortality rates. Only Robin Hood Index showed a significant correlation with the mortality rates.

For Salvador, SILVA ET AL (1999) did not find a significant correlation between age adjusted mortality rate and each of three socio-economic variables: income of the head of the household, education of the head of the households, and proportion of households in favelas. They found a significant correlation between infant mortality and the proportion of households in favelas.

In contrast, this study found marked differences and significant results in relation to the association between mortality and social factors for both sexes and for the age groups of under 5, between 15 and 64 years old, and 65 and over years.

Few areas were used for São Paulo and Rio studies (Table 2-1). For example, in São Paulo, with 9,5 million people, 56 areas were used (Stephens et al, 1994). In Rio, with 5,5 million, only 24 areas were used (SZWARCWALD AND CASTILHO, 1998 and SZWARCWALD ET AL, 1999). Therefore the areas used for both studies are very heterogeneous.

The composite index used in São Paulo grouped two subsets of variables that tend to correlate to each other in Brazilian cities, as it is showed in Table 4-2. Education tends to correlate to income and also to crowding. Water access tends to correlate to sewage access.

Further weighting procedures may have overweighed the index toward income variable[43]. That might be affected the accuracy of the index.

In Salvador, the effects of education and income were separately analysed. Not surprisingly, these variables presented similar correlation values in relation to adjusted mortality rates and infant mortality. They did not find consistent correlation coefficients between socio-economic indicator and mortality rates. They used three cut points for each variable, classifying the area according to the dominant proportion of one out of three cut points[44]. This erratic cut point procedure may have affected the accuracy of the index.

This study might be less affected by those problems because the reference populations (PUs' populations) were at a smaller level of heterogeneity in relation to the exposure factors. In addition, the risk factors were treated individually in the statistical analysis. Some results of this study are consistent with studies related to Brazilian and European cities.

In the Chapter 5, the findings from mapping the all causes SMR are consistent to those related to London (MCCARTHY AND FERGUSON, 1999). They found higher SMRs in areas with more unemployment and social deprivation. Annex 6 shows a similar pattern for Belo Horizonte. Favelas show the highest SMRs.

The findings of this research are consistent to those found in Barcelona (BORELL AND ARIAS, 1995), London (BENZEVAL ET AL, 1992), Scotland (CARSTAIRS AND MORRIS, 1991), and Bristol (TOWNSEND ET AL, 1985). BORELL AND ARIAS (1995) found a high correlation (0.824) between age adjusted mortality rates and proportion of illiterate population aged 15-64. BENZAVAL ET AL (1992), using a composite index of 16 variables, found that the most deprived areas presented higher SMRs. CARSTAIRS AND MORRIS (1991) found associations between composite deprivation index and SMRs for all ages, 0-4 years old and male e female of 0-64. TOWNSEND ET AL found a significant correlation between mortality rates (15-64 years old) and crowding. Regarding to children under 5, the correlation found between low

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43 Using the Delphi T echnique, the variables ranking was: income=1, education=2, sanitation=3, water=4, and crowding=5 (STEPHENS ET AL, 1994).

44 Proportion of head the household with income of up to 2 minimum wage (MW), 2-5 MW, and over 5 MW. Proportion of head of the household with education of up to 7 years of education, 8-14 years of education, and over 14 years of education. In each of them, the dominant proportion defined the ward classification. When the difference of the proportions were less than 10%, the contribution of each group was distributed by interpolation (SILVA ET AL, 1999).

education and higher mortality risks in this research is consistent with that found by STEPHENS ET AL (1994) for São Paulo.

In this study, significant diffrentials were found for males and females in the age groups 15-64 and 65 and over (Table 5-7). Notably the wider differences were observed in the females (15-64 years). In this year-group the mortality rate ratios for 5th quintile was 2.46 (females) and 1.59 (males). Cardiovascular diseases have a significant role in this differential. The specific mortality rate ratios for 5th quintile was 3.76 (females) and 1.99 (males).

The hypothesis derived from those findings is: in Belo Horizonte, socio-economic differences produce greater differences for women in terms of risk factors related to cardiovascular diseases. This corroborates with the findings of DUNCAN ET AL (1993) for Porto Alegre, a Brazilian city with similar socio-economic and demographic indicators as Belo Horizonte. DUNCAN ET AL (1993) found that in relation to sedentary during leisure time, sedentary overall, and obesity, low educated females presented higher odds ratios than the highest educated (1.5, 1.6, 2.8, subsequently). Lower educated males presented lower odds ratios than the highest educated for these risk factors. However hypertension risk is higher among low educated males (2.4 OR) while is not present among the females (0.82 OR).

In the Chapter 6, the favelas' population presents 34% higher risk of death from all causes than the non-favelas population. If controlled for the proportion of low-educated head of the household, the risk falls to 12% (Table 6-4) but remains statistically significant. This implies that the physical environmental variables in favelas have smaller impact in all cause of diseases than in infectious and homicides, as is showed in the following sections. SILVA ET AL (1999) obtained different result from Salvador, using favela as indicator in a different way. They did not find a significant correlation between "the proportion of favela households within the ward" and age adjusted mortality rates (all causes of death). However they found a significant result for infant mortality.

7.3.2 Infectious diseases

Chapter 5 shows a significant and substantial association between infectious diseases and the proportion of low-educated head of the household. Areas with an high proportion of low-educated head of the household present 87% greater risk than those in areas with a low proportion[45]. The disease mapping showed that the highest rates occur in favelas.

In the univariate analysis, the association between mortality and all physical environmental variables are significant. In the multivariate analysis stage, after controlling for socio-economic and other environmental variables, the environmental variables presented non-significant associations.

In Chapter 6, after controlling for the proportion of low-educated head of the household, the population from favelas present 59% greater chance to die due to infectious causes than those from non-favelas (Table 6-4).

The results suggest that physical environmental disadvantages may lead to greater risks of dying due to infections. The differences can also be consequence of differences in access to health care provision across the areas. Access to health care, especially to hospitalisation, was not studied in this research. However, health services system in Brazil is extensive and public. It is unlikely that the poor population from favelas may have less access to hospitals than the poor living in the other areas of the city.

7.3.3 Diarrhoea, pneumonia and malnutrition (under 5 years old)

In the Chapter 5, the combined illnesses of diarrhoea, pneumonia and malnutrition present association with all six tested variables but rubbish collection (univariate analysis).

The main limitation in the analysis is the effect of different independent variable over different cause of death (diarrhoea, pneumonia and malnutrition). Each cause of death has its

[45] AIDS is not included in the group of infectious diseases. However, AIDS was tested isolated, showing a non-significant association with low education.

own pathway. If in one hand, low education of the head of the household is associated with mortality due to combined illness of diarrhoea, pneumonia and malnutrition in Belo Horizonte. In the other hand, in other Brazilian studies, women illiteracy has been found associated with diarrhoea (DE-SOUZA ET AL, 1999) but not with pneumonia (VICTORA ET AL, 1994, NIOBBEY ET AL, 1992).

In Brazil, water has been found associated with diarrhoea (MERRICK, 1983, VICTORA ET AL, 1988). ESREY (1990, 1991), in an extensive review (144 studies), examined the impact of sanitary interventions on diarrhoea. Sanitary interventions alone were responsible for reduction of 55% of infant mortality, suggesting that better access to sanitation have a strong impact on child survival. Neither water, nor sanitation have a direct impact on pneumonia.

In this study the three diseases were analysed together, therefore the positive correlation of one exposure variable with the combining outcomes should be interpreted as the trigger mechanism that may contribute to infections. Thus, water may contribute to infection A and subsequently to nutrient deficiency and depletion of immunologic system. This increased stage of vulnerability magnifies the risk of the child contracting infection B. This in turn starts a new cycle of infection/malnutrition/ immunologic deficiency.

The non-significant results for rubbish collection contradicts the positive association found by CATAPRETA AND HELLER (1999) for morbidity due to diarrhoea. They studied the diarrhoea morbity in seven favelas of Belo Horizonte for the year of 1995. They found that children living in areas without rubbish collection have 40% greater chance to have diarrhoea than those served by the collection. It is possible to argue that high morbidity not necessarily produces high mortality. Lack of access to rubbish collection correlates with high morbidity rates in Belo Horizonte, but those cases have not been converted in fatalities.

In the multivariate analysis, after adjusting for the confounding effect of the exposure variables on each other, the only association that remained statistically significant was that with access to sewage. Rates are elevated in 2nd quintile to 5th relative to the baseline ($p=0.05$, heterogeneity test), but there is no evidence for trend from 2nd to 5th quintiles (Table 5-11). Increasing access to sanitation can reduce the children mortality due to diarrhoea. This may then, reduces the vulnerability to be reached by other lethal infections.

In the Chapter 6, when adjustment for education of the head of the household is made, favela population presents 62% greater chance to die due to those combined diseases than the non-favela population. That implies lack of sanitation interacting with other factors (possibly unhealthy behaviours) increase the risk for children of dying due to diarrhoea, pneumonia and malnutrition.

Mapping mortality ratios has revealed unexpected results in two areas. The favelas Jardim Felicidade and Prado Lopes presented low mortality rates. That may be due to the effectiveness of local health policies or due to loss of data.

7.3.4 External causes of death

In Belo Horizonte, the risk transition has produced a potential dangerous environment for Belo Horizonte citizens. According to data provided by National Department of Traffic (DETRAN, 1995), from 1980 to 1994, the number of cars increased 2.5-fold while the population increased less than 16% in the same period. As a consequence the car/person rate jumped from 158 (/1000) to 346 (/1000).

Violence has also increased in Belo Horizonte City[46]. PAIXÃO AND ANDRADE (1992) observed the rates of homicide and attempted homicide in the city from 1985 to 1990. Homicide rates increased from 6.15 per 100,000 to 10.95, while attempted homicide rate elevated from 47.16 per 100,000 to 62.51.

In Annex 6, the disease map for external causes (Figure A6-9) presents in general higher SMR in favelas and periphery. This is consistent with the maps produced by the Belo Horizonte Municipality using a composite index of security variables[47], which indicated that all favelas but one presented high level of insecurity (PBH, 1996).

Univariate and multivariate analyses identified associations between external causes and the proportion of low-educated head of the household, and crowding. These associations might

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[46] According to MALETTA (1997), before 1980, the external causes were 10^{th} most frequent cause of death in Belo Horizonte. In 1991, they were ranked as 3^{rd} leading cause.

[47] The index was constituted by 5 sub-set of variables: police attendance (2 variables), personal security (7 variables), propriety security (3 variables), traffic security (7 variables) and environmental security (1 variable) (PBH, 1996). Data from 1994 was used in this research. This researcher has participated in the team who developed and tested the index.

be interpreted according to their plausible links with some external causes. In this context, crowding can operate as a proxy for socio-economic condition rather than a specific variable.

When adjustment was made for confounding variables and the mutual confounding effect of the variables on each other, population from areas with highest rates of crowding presented 95% greater chance (p=0.03, P-value for trend) to die due to external causes than those living in areas that constituted the baseline. This is consistent to STEPHENS ET AL (1994) findings related to São Paulo. In this city, population from most deprived areas has 83% greater chance of dying due to external causes than those from the affluent areas.

In the Chapter 6, when favelas areas are compared to non-favelas, favela inhabitants presented 26% greater chance to die due to external cause (Table 6-4). This relatively small difference is consequence of the non-association of the MVTA with living in favela. This will be better seen in the following sections, where homicide and MVTA will be looked in detail.

7.3.5 Homicide

Violent criminality and organised crime have risen in Brazil. They have not been subjected of efficient and co-ordinated policies by the state (PINHEIRO, 1995). In Rio, drug dealing has been associated with violence epidemics (SZWARCWALD AND CASTILHO, 1998). Violence related to drugs has also been seen in other Brazilian state capitals.

The sociologist PAIXÃO (personal communication in 1996) stated that drug activity in Belo Horizonte is neither intense nor violent as in Rio in 1994. He explained that the population of Rio is 3.5-fold greater than Belo Horizonte. Rio has access to the Atlantic Ocean and the most intense flight activity within Brazil. Rio is not only a bigger market but also a strategic route for South American drug smuggling to Europe and USA.

In Brazil, ecological studies have found associations between homicide and adverse socio-economic conditions. In São Paulo, BARATA ET AL (1998) found a strong association between homicide and deprivation area. They classified the areas according to the demographic variables: crowding, number of rooms per household, illiteracy rate and average income. In

Rio, SZWARCWALD ET AL (1999) found associations between homicide rate and Robin Hood Index, and also population living in favelas.

In Belo Horizonte, the homicide map has indicated that the highest rates coincide with poor areas, especially favelas. It is substantially different from Rio, where the homicides had initially spread along the motorways and the coast (SZWARCWALD AND CASTILHO, 1998). One possible explanation is in Belo Horizonte, in 1994, interpersonal crime was the most important cause of homicide, while in Rio the organised crime was the main cause of homicide. Access to the motorway and ports are logistic factors related to drug dealing, but this has no relationship with inter-personal homicide.

In the Chapter 5 (Table 5-15), all tested variables presented associations with homicide rate ratios during the univariate analysis. The wide difference between the 5th quintile and the base line was related to crowding (5.56) followed by the proportion of low-educated head of the household (4.33).

In the multivariate analysis, after controlling for other variables, poor public illumination remained statistically significant as risk factor. Notably, access to police was also directly associated with homicide.

The effect of illumination must be analysed carefully. Firstly, because this is due to the fact that the time that the homicides occurred was not available. Thus is not clear if they happen in time of poor or good light. Secondly, data refers to the place of residence not to the place where homicides occurred. The Police Department provided data on where the homicides, attempted homicides, found corpses[48] and suicides took place. The police data could not been linked to mortality data used in this research. Maps derived from police data did not match with homicides map produced in this research. According to police data, the highest concentration of events is in the central area of the city (6.1%). This area also presents the highest concentration of bars and restaurants within the city.

The findings suggest that a proportion of the homicides is happening far from home. In this case, poor public illumination can explain only part of the cases. This is consistent to SOUZA ET AL (1997) study about Rio. They observed that 52.1 % of the victims (10 to 19 years old)

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[48] Found corpses relate to those not determined the cause of death in the moment they were removed by the police.

of the homicides in central area were from other areas while in the most deprived area the proportion of outsider victims was 18.8%.

The inverse correlation between access to police and homicide has previously been explained as confounding by indication. Police of Belo Horizonte is among the most prestigious police forces in Brazil (BEATO, 1998). However, tackling homicide problems requires more than policy apparatus. In São Paulo, the distribution of police resources is inversely associated with homicides (AKERMAN, 1997) because police has prioritised areas with high concentration of theft. As a consequence, theft rates show directly association with police resources allocation. Therefore, police allocation has not been sufficient to prevent homicide in Belo Horizonte neither theft in São Paulo.

In the Chapter 6, the effect of socio-economic variable was controlled in the multivariate analysis in order to measure the impact of environmental variables in Belo Horizonte. Favelas' population has 105% greater chance to die due to homicide than those from non-favelas (Table 6-4). That implies the most vulnerable population for homicides is in favelas, apparently linked to socio-economic disadvantage and also the unhealthy environment. This is consistent with the findings for Rio and New York. An association between favelas and homicide has been found in Rio (SZWARCWALD ET AL, 1999). Also in New York, the Harlem presented greater mortality rates than the national average (MCCORD AND FREEMAN, 1990). However, while those from favelas are more likely to be victims of homicide it is not clear if they die in the favelas or elsewhere in the city.

The dynamics of violence are complex, involving many variables. In the final section, that item will be discussed using the concepts of social exclusion.

7.3.6 Motor vehicles traffic accidents (MVTA)

The data suggest that the deaths due to MVTA are associated with social deprivations but not with living in favelas, indicating that restricted traffic in favelas reduces MVTA risk for young, old and possibly female populations.

In this study is worth to remind that information related to the place of the accident was not linked to death certificate. As a consequence, time and place of the accident could not be studied. This is the major limitation of this analysis, because three out of four studied variables are related to the place of the accident while the deaths are aggregated according to the place of residence. Excluding the proportion of low educated head of the household, the exposure variables are related to unknown fraction of the cases.

The map of MVTA (Figure A6-11) presents the periphery of the city concentrating the highest rates. Three favelas presented in the group of the lowest rates of mortality due to MVTA. Notably, the analysis comparing favelas to non-favelas presents no risk difference between the groups.

Data from National Department of Traffic (DETRAN) and the police was further analysed. In 1994, the DETRAN registered 27,560 MVTA in Belo Horizonte. Among those 40% involved victims (4.3% died during or immediately after the accident). In the same year, the police department registered only 20 accidents involving victims in the favelas of Belo Horizonte. Cars in favelas are rare because the traffic is very restricted, therefore the frequency of vehicle accidents is not significant.

In the Chapter 5, the univariate analysis showed a positive correlation between MVTA and low education. This is consistent to a recent published study about Rome (MICHELOZZI, 1999), where an association between MTVA and deprivation was found. Another Brazilian study (SOUZA, 1993) found a high proportion of low educated persons (81%) among the victims of MVTA in Duque de Caxias, a city that belongs to Metropolitan Region of Rio.

Living in areas that contain high proportion of motorways and primary roads did not present an association with MVTA. Access to police did not present association with MVTA either.

Poor public illumination presented a positive association with MVTA in both univariate analysis and multivariate analysis. In fact, it was the only variable to remain statistically significant in this stage. However, the variable might be operating as a proxy for socio-economic status considering that part of the accidents occurred far from home and during the daylight. In Rio, SOUZA ET AL (1997) found that in the accidents in the central area more than 80% of the victims were from other areas, while in deprived areas 83% were local residents. LADEIRA (1995) studying patients hospitalised in four public hospitals of Belo Horizonte due to MVTA (in November of 1994), found a high concentration of the accidents around the central area of the city (27% of all accidents that happened in Belo Horizonte). He also found that 51% of the accidents occurred during the day.

7.4 Epidemiological transition and social exclusion in Belo Horizonte

This section focuses on the results on the light of the epidemiological transition and social exclusion theories. The basic concepts of each of these theories are initially presented but the emphasis is in the contribution of the theories for building a broad framework able to articulate the evidence brought by this research with the possible macro-determinants of ill health process.

7.4.1 Epidemiological transition in Belo Horizonte

The epidemiological transition refers to "the changes in frequency, magnitude and distribution of the health conditions expressed in death, disease and disability" (FRENK et al. 1989_a). In a pragmatic definition, PHILLIPS (1994) considered the epidemiological transition "as a way of providing a general picture of the major determinants of death and the ways these were interlinked with population change".

In the Brazilian South-eastern cities, where urbanisation is associated to economic development, the changes in mortality patterns seem to move towards the advanced transition level (OYA-SAWYER ET AL, 1987). However, different stages of the epidemiological transition can be present when looking at intra-urban differentials (HARPHAM AND REICHENHEIM, 1994).

According to the previous studies, the main characteristics in the Brazilian route to the epidemiological changes are: 1) great endemics remain in some regions, 2) the mortality rates are still high when compared to developed countries, 3) there are important geographical variations within the country related to epidemiologic and health care profiles (BARRETO AND CARMO, 1995, ARAÚJO, 1992, PRATA, 1992).

The findings of this research support the thesis that Brazilian big cities have produced a complex and diversified mortality pattern. Those cities are experiencing a multiple transition process, in which infectious diseases in adult ages have been replaced by homicides in poor areas. In the past, the state failed to deliver sewage and clean water to the poor, especially in *favelas*. Nowadays, it fails to include those populations in the society in equal terms regarding to economics, civil and social rights.

As was possible to demonstrate, the epidemiological profiles vary across the geographical units in Belo Horizonte. The poorer areas, especially in favelas, face the double burden of diseases, encompassing populations with higher risk to die due to infectious diseases (under 5), homicides, cardiovascular and respiratory diseases. This can impact the demographic structure of the population in two ways: producing excess of deaths between poorer population and interfering in the fertility levels.

In the figure 5-1, areas with low proportion of low-educated head of the household present a modest mortality and a recent fertility drop in 1991. The pearl shape gets an accentuated contour in 1996. The notable increase of the proportion of young adults (15-19, 20-24) may be a consequence of in-migration. Belo Horizonte has one of the highest concentrations of universities and colleges in Brazil. However that does not explain why the same effect is not present in 1991. That phenomenon may be consequence of methodological change in the population census related to the definition of the head of household, or a seasonal variation in high education demand due to economics or cultural motivations.

The pyramids representing areas with high proportion of low-educated head of the family indicate a still high fertility and moderate mortality in 1991. The narrower pyramid base in 1996 suggests that the fertility transition may have started. The still large basis may be the consequence of demographic momentum, when a still large female population (at fertile age) is producing a large number of children despite the small fertility rate of the whole population. However, that can also mean a less determined birth control attitude faces the uncertainties of the child survivorship[49].

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[49] According to CHESNAIS (1992) the fertility fall is considered a dependent variable of mortality decline, but influenced, reciprocally, by economic variables.

7.5 Social exclusion and health in Brazilian cities

The most common use of the concept of social exclusion has been the lack of access to multiple dimensions of the social life due to imposed circumstances (TOWNROE, 1996). The components of the social exclusion can be economics (production and/or consumption), legal, political and cultural (SHAW ET AL, 1999). In Brazil, BUARQUE (1993) defined social exclusion as a social apartheid because it is a consequence of economic and social policies inducted and maintained by the state.

The process of social exclusion is associated with health inequality because it shapes the health vulnerability of a given population. In one hand, the excluded are denied the basic assets for health (nourishment, education, housing, adequate social and physical environment, etc). On the other hand, the excluded have restricted or no access to treatments, social support and rehabilitation programmes.

WHITE (1998a) had represented the social exclusion process in four levels: macro determinants, elements and affected groups/affected indicators, and affected areas. Figure 7-1 presents an adaptation of White's model. The main differences are in the first and third level. Macro determinants, and affected groups and indicators are different in the Brazilian context. Furthermore, there are conceptual differences regarding to elements of social exclusion (intermediate level).

In Brazil, the five macro-determinants of social exclusion cover the economic, social and cultural dimensions of society. The economic model in Brazil is defined as excluding because despite of economic growth after II World War, it has not produce opportunities in the formal labour market for a considerable part of the society. In 1990, 35% of the whole Brazilian labour force was classified as engaged in informal economic sector (IBGE, 1994). That type of relationship is done outside any protective legal framework. Those who are not self-employed become, in practical terms, excluded from the labour rights (LAMPREIA, 1995). That process varies across the Brazilian states. While São Paulo State presented 22% of its labour force attached to the informal sector, in Piauí State the percentage reached above 65%.

The socio-demographic changes among the poor point toward a lower decline in fertility, intense migration toward middle size cities (intermediate industrial poles as suggested by

CAMPOLINA, 1999) and lower gains in life expectancy. These components of the demographic dynamics imply a growing dependent population in urban areas, colliding with decrease in social benefits and social public services erosion.

In the last five years, economic stability has been the main item in the governance agenda. As part of fiscal deficit control policy, Brazil has promoted a dramatic change in the retirement policy for public servants, extending the minimum time for retirement, reducing the pensions, and introducing a new taxation system for pensioners.

In the health system "chronic under-financing has led to deterioration of facilities, shortages in essential inputs, and poor remuneration of professionals, leading to inefficiency, poor quality of care, a demoralized work force and fraud" (WORLD BANK, 1996, p. 12).

The first element of the social exclusion refers to exclusion from participating in civil society though political under-representation, manipulation and clientelism. According to KOWARICK (1997), more than 20 years after the ending of the dictatorship regime, the Brazilian political system has not been able to consolidate individual and collective rights, failing to extend the full citizenship for all.

The second element refers to inability to deliver goods and services to groups with particular demands. Even the roads of affluent areas of Belo Horizonte, the environment is not adapted for disabled people. Wheel chairs and blind people have troubled to use the street where frequent access ramp for the cars are ostensibly built up over the pavement level.

The third component relates to both economic production and social production. The former refers to the lack of access of former labour market. The latter refers to feeling useless, devaluated, unprotected, and isolated: unable to give a decent social contribution (WILKINSON, 1996).

The fourth component, and the most stressful according to WHITE (1998a), refers to inability of the state to provide the basic social goods and services for the whole community. As was showed in this study the poor areas of Belo Horizonte still lack basic sanitation services. A study of quality of life in Belo Horizonte (PBH, 1996), carried out by the municipality, also showed that the poorer areas in economic terms are also poorer in relation to social care, housing, and facilities of education, health culture and leisure.

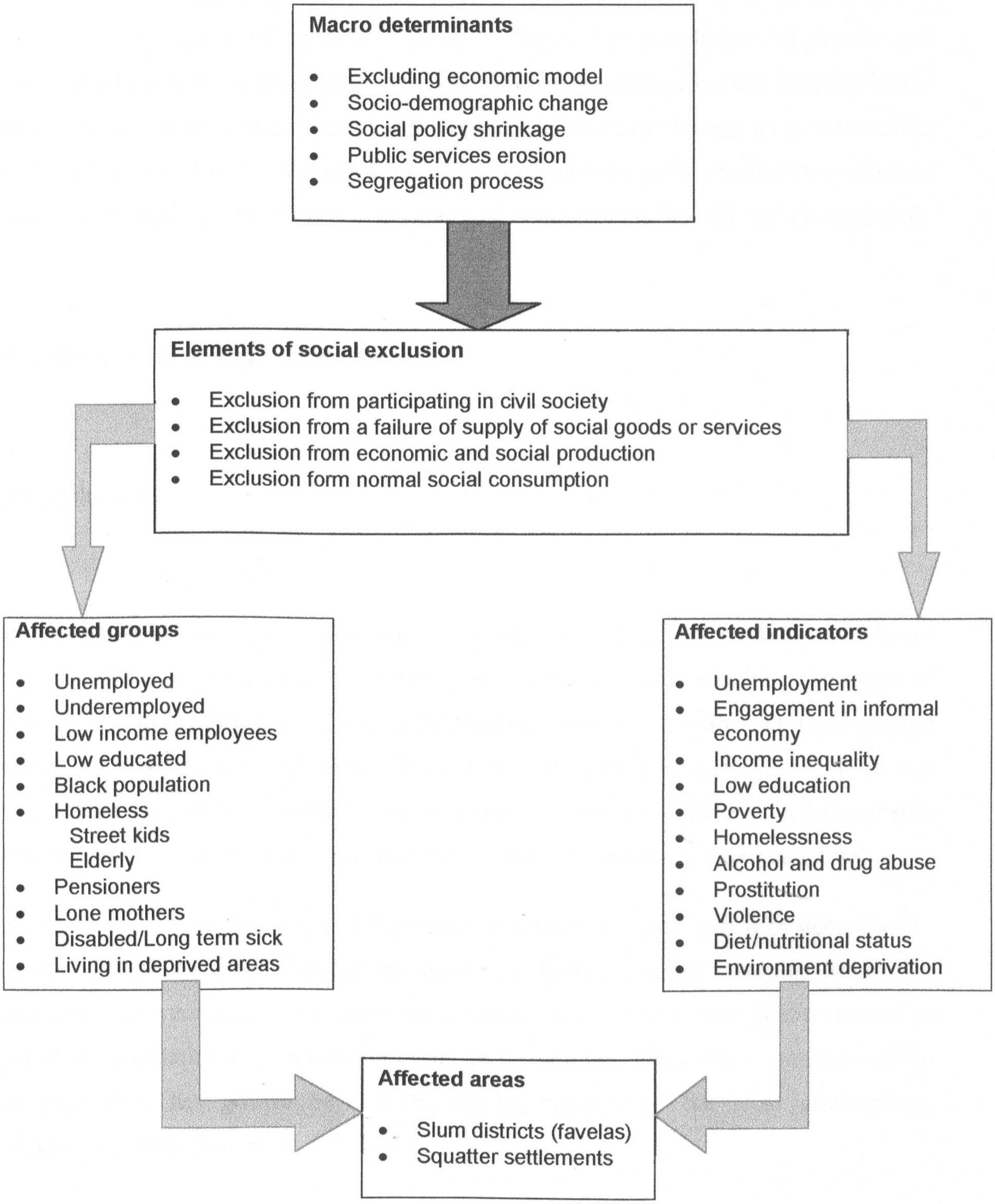

Figure 7-1 The process and outcome of social exclusion in Brazilian cities (adapted from WHITE, 1998a)

The extreme of social exclusion is socio-spatial segregation. In this context, social polarisation and social segregation "impede the ability of the residents to grasp whatever opportunities exist for social mobility" (SCHILL, 1994). The populations of *favelas* and *conjuntos habitacionais* (squatter settlements) are not only excluded from the Belo Horizonte itself, but those spaces became symbol and metaphor of exclusion though an process called "adressism" (WHITE, 1998b). The *favelados* and *suburbanos* are in the imagintive creation of the urban Brazilians the "other", the archetypes (and denominations) of the socially excluded.

7.6 Conclusions and policy implications

7.6.1 Conclusions

When compared to rural areas, cities usually present lower levels of mortality and lower levels of fertility, suggesting that the urban population have better conditions in terms of access to education, health care and infrastructure. However health and demographic indicators vary within the city, suggesting that the gains of urbanisation have been not equally distributed among all settlers. Socio-economic differences and uneven health patterns have been part of the urban scenario in big cities in both Western and Eastern countries.

Evidence from other studies suggests that health inequality is associated with demographic dynamics and lack of basic infrastructure. Poverty, famine and social instability has driven several processes: rural population moves to the urban areas, small city population moves to bigger cities, population from poorer areas moves to wealthier cities. As a consequence the urban population has growth beyond the service capacity of the local governments (MCGRANAHAN AND SONGSORE, 1996)

The evidences from Belo Horizonte can be used to understand the urban health environment in relation to: revealing the social determinants of health, identifying environmental factors associated with urban health problems, revealing the complex health profiles of the cities, and revealing the most vulnerable health groups. The conclusions are consistent with the hypothesis introduced in the Chapter 3:

- In Belo Horizonte, social deprived areas present higher mortality rates of all causes of death, infectious diseases, external causes, homicides, MVTA and combined illnesses of diarrhoea, pneumonia and malnutrition. This supports the hypothesis that medium size cities in developing countries, which are in an advanced stage of the epidemiological transition, socio-economic and environmental factors have a high influence on the mortality variation, and this is more pronounced for some specific causes: infectious diseases, homicides and combined illnesses of diarrhoea, pneumonia and malnutrition.

- Evidence from Belo Horizonte is consistent with evidences from other cities, which indicate that physical environmental factors can also contribute to intra-urban health inequality. Uneven distribution of urban facilities such as lack of access to water, sanitation, rubbish collection, adequate housing and neighbourhood are predictors to the excess of death.

- Evidences from Belo Horizonte support the hypothesis that the disease risks associated with all causes of death, infectious disease, external causes of death, homicide, MVTA, and combined illnesses of diarrhoea, pneumonia and malnutrition are uneven distributed in the city; shaping a process named as intra-urban health inequality. Mapping and analysing mortality variation within the city indicates that populations from different areas of the city are facing multiple epidemiological transitions. Impoverished and environmental deprived areas have experienced the double burden of diseases. These areas (the favelas) contain the most vulnerable health groups.

7.6.2 General policy implications

The health and urban policy recommendations flowing from these findings are:

1) Inserting health inequalities into the agenda. The Brazilian Federal Constitution of 1988 defined health as a right of all citzens and a duty of the State. It also allowed the creation of Unified Health System (Sistema Único de Saúde - SUS). The SUS operates under the principles of universal, fair and equal access to the health system. The Brazilian health

reform has thrived, specially regarding to the municipalisation[50] (O'DWYER, 1999). However, health indicators remain markedly uneven between (LAURENTI, 1990) and within the cities. In Brazil, specific health policies to reduce health inequalities have not been incorporated into the health agenda. This is a challenging task for the Brazilian health reform.

2) Improving quality of life of inhabitants, tackling socio-economic inequalities, promoting social integration and social stability as suggested by HABITAT (1996). Policy discussion related to homicide prevention usually focuses on gun control, policing and incarcerating. The Brazilian Congress has settled for the year 2000 the debate about the ban of the commerce of guns in Brazilian territory. This strategy has produced a pitiful result in the state of Rio de Janeiro (including the city of Rio), where a similar law was sanctioned in early 1999. Intense policing in Belo Horizonte fails to prevent homicide. In contrast, reducing social inequality and building social capital is a more challenging health policy. Improving the life quality and reducing inequalities permit an increase in the collective wellbeing, reducing violence and improving population health (KAWACHI ET AL, 1999).

3) Creating healthy household and neighbourhood. The requirements for producing a healthy household and environment are similar in all urban centres (BARTLETT ET AL, 1999, WHO 1995). They encompass access to water, sanitation and rubbish removal, and alleviating the impact of crowding. BARTLETT ET AL (1999) argue that crowding may be strategy for survival among some poor families. Price, location and accessibility to urban facilities interfere in the decision to keep a considerable number of relatives together. This author of this study supports the idea that improving the quality of the surroundings can alleviate the impact of crowding.

4) Defining adequate policies for dealing with access and use of renewable resources (water, food and fuel supplies), non-renewable resources (oil, natural gas and some minerals), non-reusable wastes (persistent chemicals, nuclear wastes, and many greenhouse gases). The high urban consumption encompasses non-reusable resources, being associated with high levels of waste generation, including non-reusable types (MITLIN AND SATTERTHWAITTE, 1996).

[50] According to O'DWYER (1999) 95% out of 5507 Brazilian municipalities have totally or partially managed the primary health care.

Those issues point toward the fields of social and environmental sustainability[51]. Urban health depends on the ability of local governments in developing the institutional structure able to promote a sustainable development (HABITAT, 1996). Local governments faces important challenges, such as: lack of financial capacity, lack of regulatory frameworks, competing demands, volatile political commitment, lack of transparency and accountability, and political manipulation or inability in involving community (BARTLETT ET AL, 1999, WHITEHEAD, 1998).

7.6.3 Specific implications for Brazilian health indicators

These section presents recommendations related to improving the quality of mortality data in Brazil and implications related to the use of the *planning unit* networks in Belo Horizonte city.

National Mortality data

The main problem of intra-urban studies of mortality in Brazil is the quality of the mortality databases. Address misclassification has limited the investigations. The Ministry of Health has recently improved the mortality system by decentralising data processing of death certificates. Since 1999, the health department of the municipalities automatically processes the death certificates. Another improvement relates to the inclusion and specific field for zip codes in death certificates and in the electronic form of Mortality Information System (MS/FNS, 1999a, MS/FNS, 1999b). However, the effects will be restricted if:

1. The cities could not produce and updated address database, including shantytown areas.

[51] "Social sustainability is people oriented, identified with the stability and the cultural diversity of social systems; and environmental sustainability refers to the preservation, the resilience and the adaptation of physical and biological systems" (PUGH, 1996a, p.1)

2. The health department of the municipalities could not process adequately address, because of the lack of a routine for data entry.

3. The population, especially from shantytown areas, could not inform precisely the address.

The first recommendation in this field is that the Ministry of Health, through the National Centre of Epidemiology (CENEPI), should recommend an articulation between municipalities and water and electricity companies and the National Mail in developing an updating address database for the cities. For shantytowns that are partially served by the water companies, the Energy Company[52] and the National Mail can help the Municipalities to produce a comprehensive address database.

The key aspect in the routine for data entry is how identify the correct address if the zip codes are not available, what is a majority of the cases. The Brazilians do not usually know their owns zip codes. The recommendation is to develop a routine for dealing with unclear address in the death certificates, using the health centres network to correct unclear address information. The routine should be included in the Manual of the Mortality Information Systems (Manual de Procedimento do Sistema de Informações Sobre Mortalidade).

PU network in Belo Horizonte

Since 1994, the Municipality has invested in defining a geographical network that could suit as a reference for urban planning and policy. The efforts of this research in defining a geographical network allowing for compatibility between census data and mortality data have helped the municipality to achieve its goals. The Municipality subsequently adopted the redefinition of PU network (Annex 2) as the cartographic reference for planning studies (OLIVEIRA ET AL, 1996).

The Municipality has used the PU network for producing:

[52] In Belo Horizonte, the Energy Company has proved to have a comprehensive database. A copy of the energy bill is requested when applying for a place in public school. The photocopy is used confirm address of the parent or guardian of the applicant. In 1998, only 0.7% out of 33,000 applicants could not provide a photocopy of the energy bill. All addresses from the photocopies could be geocoded (PINTO, 1999).

1. The basic studies of Directive Urban Plan of Belo Horizonte and the Bill of Use and Occupation of the Land (PBH, 1995). The studies led to the Urbanistic Legislation of the Municipality of Belo Horizonte, being sanctioned in 27th August of 1996 (PBH, 1996b).

2. The Index of Urban Quality of Life – IQVU (PBH, 1996a). The index has been used by the Planning Department to evaluate the demands for urban services and infrastructure in the PUs.

3. The Map of Exclusion. The *Planning* Department of the Municipality in co-operation with the Catholic University of Belo Horizonte is producing the map of exclusion, using the methodology developed for São Paulo (Spozati, 1996).

The process of making the PU network compatible with census tract network had permitted an intense dialogue between the Municipality and the National Census Bureau (IBGE). For the first time in Brazil, a municipality could interfere in the definition of the census tract network. This has occurred in relation to the Special Census of 1996 and to the Census of 2000.

The Municipality has "learned" the importance and the advantage to define geographical network compatible to the census tract, the IBGE has "learned" to consider urban space specificity in designing its census network. The main advantage in this relationship for both agencies and for the researchers is the maintenance of geographical compatibility between the networks. This type of relationship between the agencies responsible for producing geographic data should be also stimulated.

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ANNEX 1

Table A1-1 Total population, population under 5 and deaths due to selected causes of death in 75 PUs of Belo Horizonte (1994)

Planning Unit	population total	population under 5	total deaths	infectious	diarrhoea, pneum & maln.	neoplasm	cardio vascular	respirator.	external causes	MVTA	homicide
Abilio Machado	49.984	4.115	279	9	6	45	90	39	12	6	2
Anchieta/Sion	41.875	1.899	197	4	2	41	59	34	12	5	1
Antonio Carlos	61.781	5.089	459	25	12	65	164	50	35	11	11
Bairro das Industrias	12.116	1.050	65	3	1	12	19	11	8	1	3
Baleia	4.562	612	31	3	3	6	5	5	3	1	1
Barragem	14.816	1.917	55	4	6	3	20	9	8	1	5
Barreiro de Baixo	40.112	3.392	156	9	6	15	45	26	17	9	2
Barreiro de Cima	46.526	4.940	175	10	8	21	52	24	24	13	6
Barreiro-Oeste	45.849	4.449	192	16	8	20	60	22	19	7	5
Barro Preto	6.800	241	54	3	0	10	19	7	3	1	2
Barroca	50.254	2.560	244	6	2	46	89	28	18	6	2
Belmonte	35.866	3.641	154	9	6	19	42	13	23	15	0
Belvedere	2.930	117	6	0	0	4	0	0	1	1	0
Betania	37.714	3.537	160	5	3	18	53	20	16	8	2
Boa Vista	48.737	4.392	294	20	13	42	93	48	23	7	6
Cabana	67.063	6.683	373	29	17	32	98	39	47	18	10
Cachoeirinha	32.776	2.650	189	9	2	32	66	29	18	5	1
Cafezal	32.986	4.125	186	24	25	14	46	23	25	4	10
Caicaras	33.000	2.538	204	6	0	43	57	28	17	13	0
Camargos	2.436	207	10	0	0	0	3	1	0	0	0
Capitao Eduardo	3.973	521	19	0	0	1	11	0	1	0	1
Cardoso	28.687	2.804	101	1	1	16	32	8	14	5	1
Centro	17.191	557	141	1	0	24	50	20	8	5	2
Ceu Azul	20.706	1.914	104	7	7	8	36	16	10	3	2
Concordia	19.195	1.397	141	5	2	25	40	26	7	4	1
Copacabana	43.405	4.503	194	14	9	14	61	23	17	9	6
Cristiano Macahdo	67.579	4.893	335	15	7	44	132	40	23	12	4
Estoril/Buritis	5.393	654	12	0	1	2	3	2	2	1	0
Floresta/Santa Tereza	34.255	2.027	215	8	3	35	75	38	8	4	1
Francisco Sales	9.258	422	82	2	0	10	28	13	4	1	0
Garcas/Braunas	2.615	261	29	1	1	4	9	2	4	1	3
Gloria	68.517	6.343	326	10	13	41	108	36	34	13	10
Gorduras	12.017	1.373	33	1	2	3	11	3	4	4	0

ANNEX 1

Table A1-1 Total population, population under 5 and deaths due to selected causes of death in 75 PUs of Belo Horizonte (1994)

Instituto Agronomico	43.327	3.164	289	16	10	35	115	37	12	4	3
Isidoro-Norte	4.813	517	23	1	0	2	7	0	3	0	2
Jaqueline	20.854	2.274	93	5	2	15	29	10	10	3	3
Jaragua	26.762	2.201	116	5	3	14	48	15	7	3	3
Jardim Europa	25.000	2.207	123	7	4	20	38	15	11	4	0
Jardim Felicidade	16.019	1.694	45	3	1	5	9	5	2	0	2
Jardim Montanhes	15.537	1.686	77	3	6	6	23	5	16	3	9
Jatoba	53.431	5.955	202	13	13	22	57	25	23	8	10
Mangabeiras	4.792	248	18	1	3	1	4	1	2	1	0
Mantiqueira/SESC	37.860	3.943	170	9	9	21	47	20	21	7	7
Mariano de Abreu	4.514	507	26	1	4	2	5	3	1	0	1
Morro das Pedras	21.155	2.673	110	10	11	4	30	14	16	2	10
Olhos d'Agua	3.622	420	14	0	3	0	5	4	1	1	0
Ouro Preto	12.750	1.163	75	5	2	10	28	7	9	4	3
Padre Eustaquio	50.996	3.347	356	13	1	54	110	48	33	8	4
Pampulha	10.839	624	48	3	3	8	20	3	3	2	0
Piratininga	41.763	4.023	185	10	6	19	59	24	25	13	5
Planalto	14.816	1.062	58	2	2	7	19	8	3	2	0
Pompeia	27.491	2.086	181	3	7	26	56	33	18	6	0
Prado Lopes	9.995	1.065	70	1	0	6	17	5	10	1	6
Primeiro de Maio	37.409	3.674	200	11	9	26	72	25	21	9	6
Prudente de Morais	18.296	1.076	51	2	0	6	18	8	3	1	0
PUC	31.880	2.410	152	4	3	17	43	24	20	8	5
Ribeiro de Abreu	21.417	2.483	94	5	5	14	27	7	10	4	3
Salgado Filho	68.300	5.861	372	22	12	41	123	48	31	13	8
Santa Amelia	25.742	1.952	116	4	1	23	40	11	15	5	4
Santa Efigenia	39.743	3.303	209	7	8	26	74	39	15	5	4
Santa Ines	9.852	681	34	2	0	6	11	2	5	4	0
Santa Maria	12.743	1.122	55	1	1	11	15	8	6	3	1
Santo Antonio	28.636	1.528	139	5	1	26	53	14	6	2	1
Sao Bento/Santa Lucia	10.969	612	43	1	1	6	10	5	4	2	0
Sao Bernardo	26.583	2.691	137	10	8	14	47	20	14	6	4
Sao Francisco	6.649	705	45	3	0	5	12	5	4	2	2
Sao Joao Batista	12.571	1.253	71	4	5	9	20	10	7	1	4
Sao Paulo	57.463	5.458	334	14	11	37	111	31	40	15	5
Sarandi	22.820	2.215	84	7	6	13	23	10	4	4	0

ANNEX 1

Table A1-1 Total population, population under 5 and deaths due to selected causes of death in 75 PUs of Belo Horizonte (1994)

Savassi	43.126	2.688	261	5	0	46	103	29	16	6	2
Serra	22.924	1.139	120	3	1	32	37	14	4	0	2
Serra Verde	14.502	1.418	59	4	5	4	14	10	5	2	1
Taquaril	36.002	4.508	208	21	20	16	63	30	22	10	7
Tupi/Floramar	44.312	4.354	203	15	9	21	55	26	20	8	3
Venda Nova	13.690	1.122	77	0	0	16	22	7	7	2	2

ANNEX 2 Matching PU and census tracts networks

Despite having a comprehensive GIS in the municipality, no one had tried to study mortality using the data provided by the municipal government. The Planing Units (PU) network did not match to census tract one. This section briefly describes the problem and also the general procedures used to minimise their effects.

Initially, 770 census tracts were not compatible to the PU network. The following procedures were used to mach the two geographical networks:

- Review the PU digitalisation, adjusting the UP border to the census tract border if the giving census tract was 95% contained into only one UP. In this phase, 636 census tracts match to the UP network.
- Re-digitalisation of PU that end in parks or other non-populated spaces (Figure 4-1). The UP boundary followed the boundary of the census tract that contained the given non-populated space. In this phase, 48 census tracts became to mach to the UP network.
- Each one of the 8 main favelas was defined as an independent PU.
- After the above measures, only 86 census tract remained non-compatible with PU network. Then, population of each PU was estimated through interpolation. The reference for the interpolation was the distribution of addresses. It was assumed that the population is equally distributed according to the address dispersion. Only residential or residential/commercial addresses were considered. The mailing list of Finance Secretary of BH for the first of January of 1994 was used.
- Six out of the PU (including a *favela*) were excluded from the study because they are atypical areas, containing small population. Barreiro Sul encompasses a mountain in the border South of the city with 1,488 population. Isidoro Sul, Pilar, Castelo, and Confisco presented respectively 1,622, 225, 2,190, and 2,218 population. UFMG delimits the campus of University of Minas Gerais, containing 28 permanent residents. As a conclusion 75 Planning Units were used in this research.

ANNEX 3

Table A3-1 Death by ICD groups in Fundação João Pinheiro and PRODABEL (1994)

YEAR ICD Group	ICD Chapters	1994 FJP	PRODABEL	FJP - PRODABEL
Infectious and parasitic diseases	Chapter I	735	582	153
Neoplasm	Chapter II	1910	1535	375
Endocrine, nutritional and metabolic diseases, and Immunity disorders	Chapter III	861	640	221
Diseases of the blood and blood-forming organs	Chapter IV	82	66	16
Mental disorders	Chapter V	106	83	23
Diseases of the nervous system and sense organs	Chapter VI	219	171	48
Diseases of the circulatory system	Chapter VII	4427	3695	732
Diseases of the respiratory system	Chapter VIII	1812	1472	340
Diseases of the digestive system	Chapter IX	732	577	155
Diseases of the genitourinary system	Chapter X	255	208	47
Complications of the pregnancy, childbirth, and puerperium	Chapter XI	7	7	0
Diseases of the skin and subcutaneous tissue	Chapter XII	27	21	6
Diseases of the musculoskeletal system and connective tissue	Chapter XIII	45	44	1
Congenital anomalies	Chapter XIV	170	137	33
Certain conditions originating in the perinatal period	Chapter XV	883	728	155
Symptoms, signs and ill-defined conditions	Chapter XVI	614	502	112
External causes of injury and poisoning	Supplementary classification of external causes of injury and poisoning	1,369	1,104	265
No definition		0	17	-17
Total		14,254	11,589	2,665

ANNEX 4 Estimating population for PUs of Belo Horizonte

The annual rate known as *exponential change* (SHRYOCK, 1976) was used to estimate population change of each planning unit. This technique was considered because geographic information related to stillbirths is not available. Thereby, other estimates methods can not be used. The formula for *exponential change* (SHRYOCK, 1976, p.215) can be algebraically expressed as:

$$r = \frac{\log \left({}^{Pn}/_{Po} \right)}{n \log e}$$

Considering the years in study, we have for 1994 the formula

$$r\ UPx = \frac{\log \left({}^{Px1996} / {}_{Px\,1991} \right)}{3 \log e}$$

The population estimates will be obtained through the *assumed rates of growth* formula (SHRYOCK, 1976, p.412),

$$\frac{P_1}{P_0} = e^{rt}$$

where the letter 't' represents the postcensal year period.

ANNEX 5

Figure A5-1
Planning Units of
Belo Horizonte (1994)

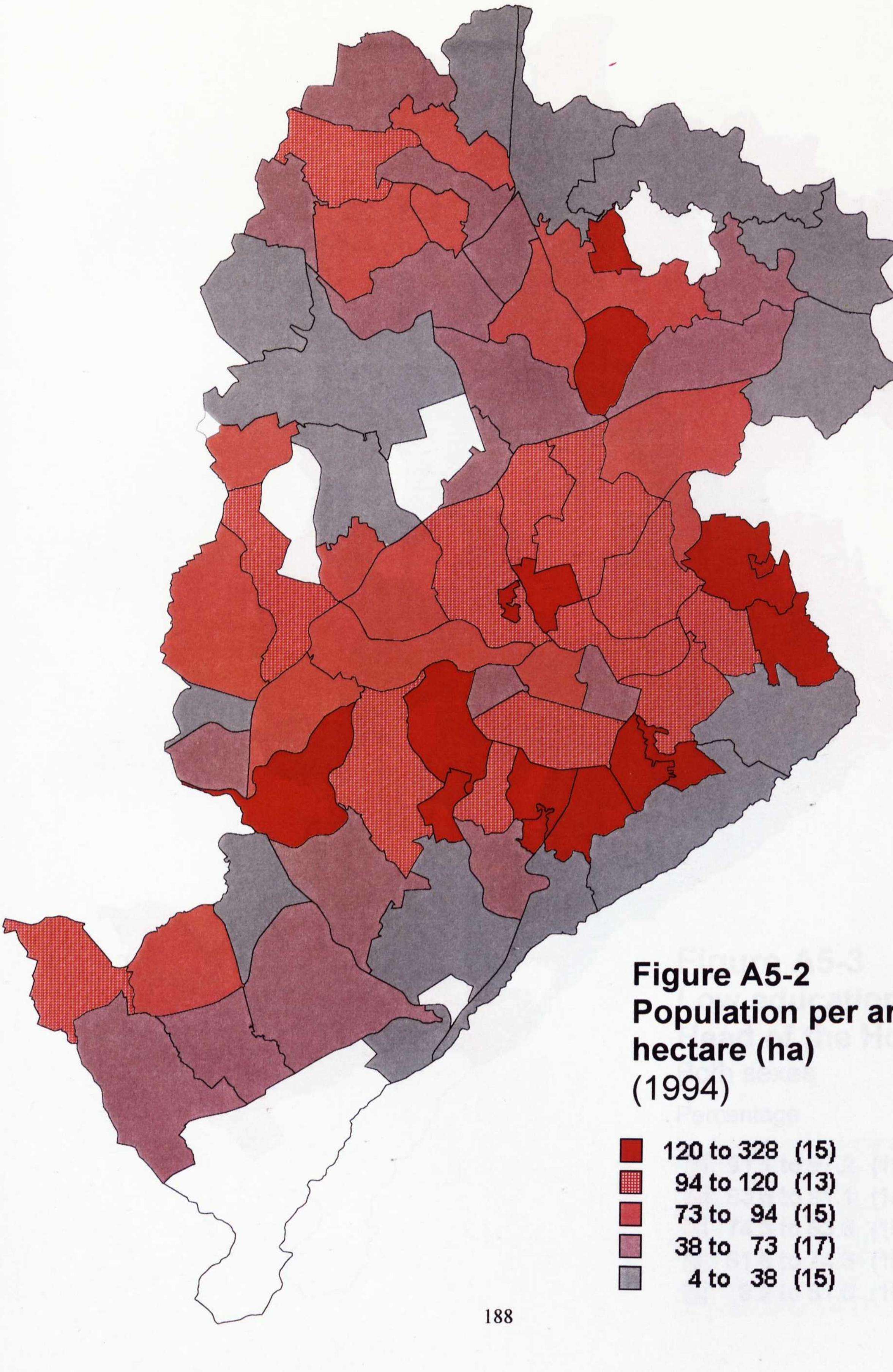

Figure A5-2
Population per area in hectare (ha)
(1994)

- 120 to 328 (15)
- 94 to 120 (13)
- 73 to 94 (15)
- 38 to 73 (17)
- 4 to 38 (15)

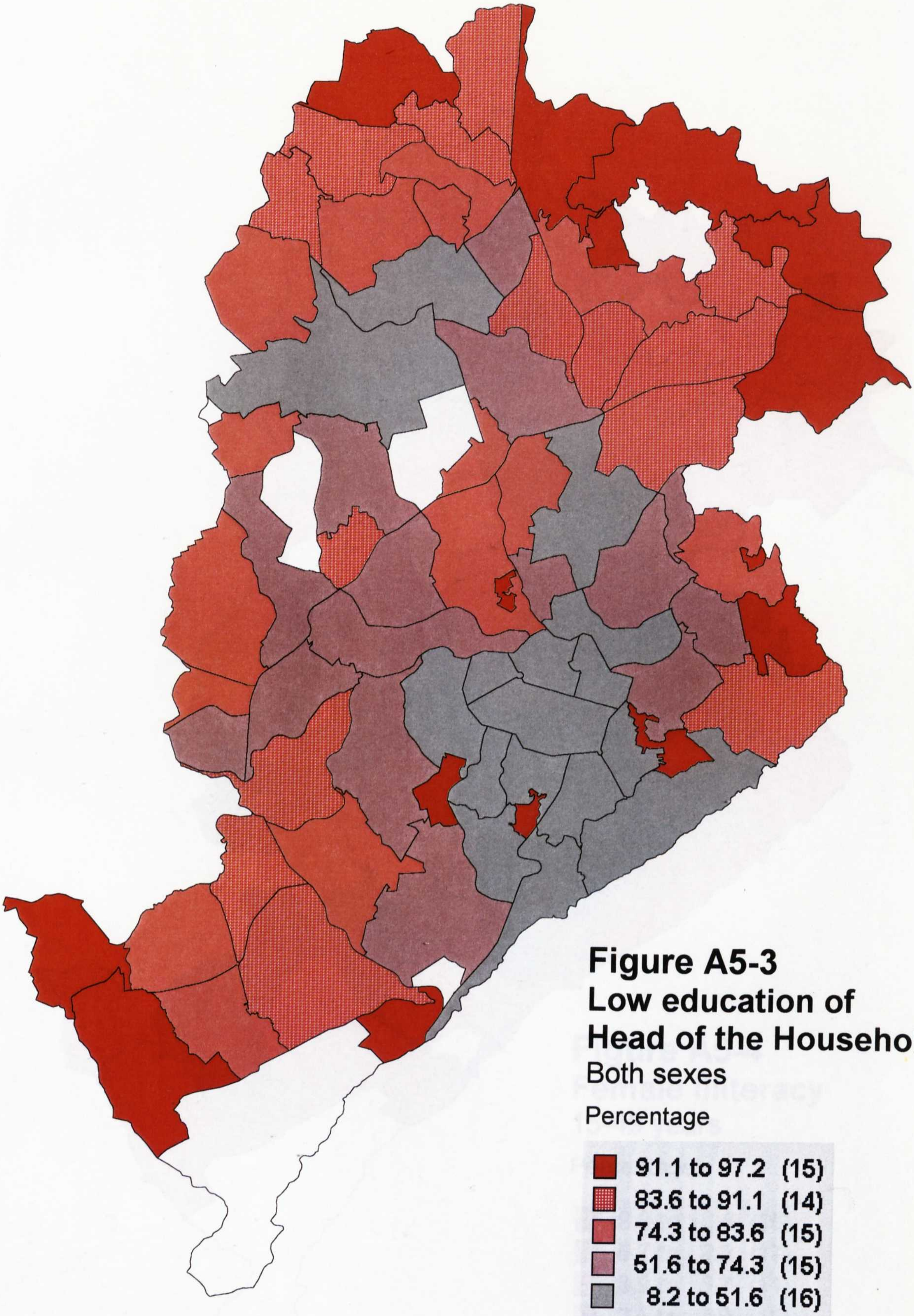

Figure A5-3
Low education of Head of the Household
Both sexes

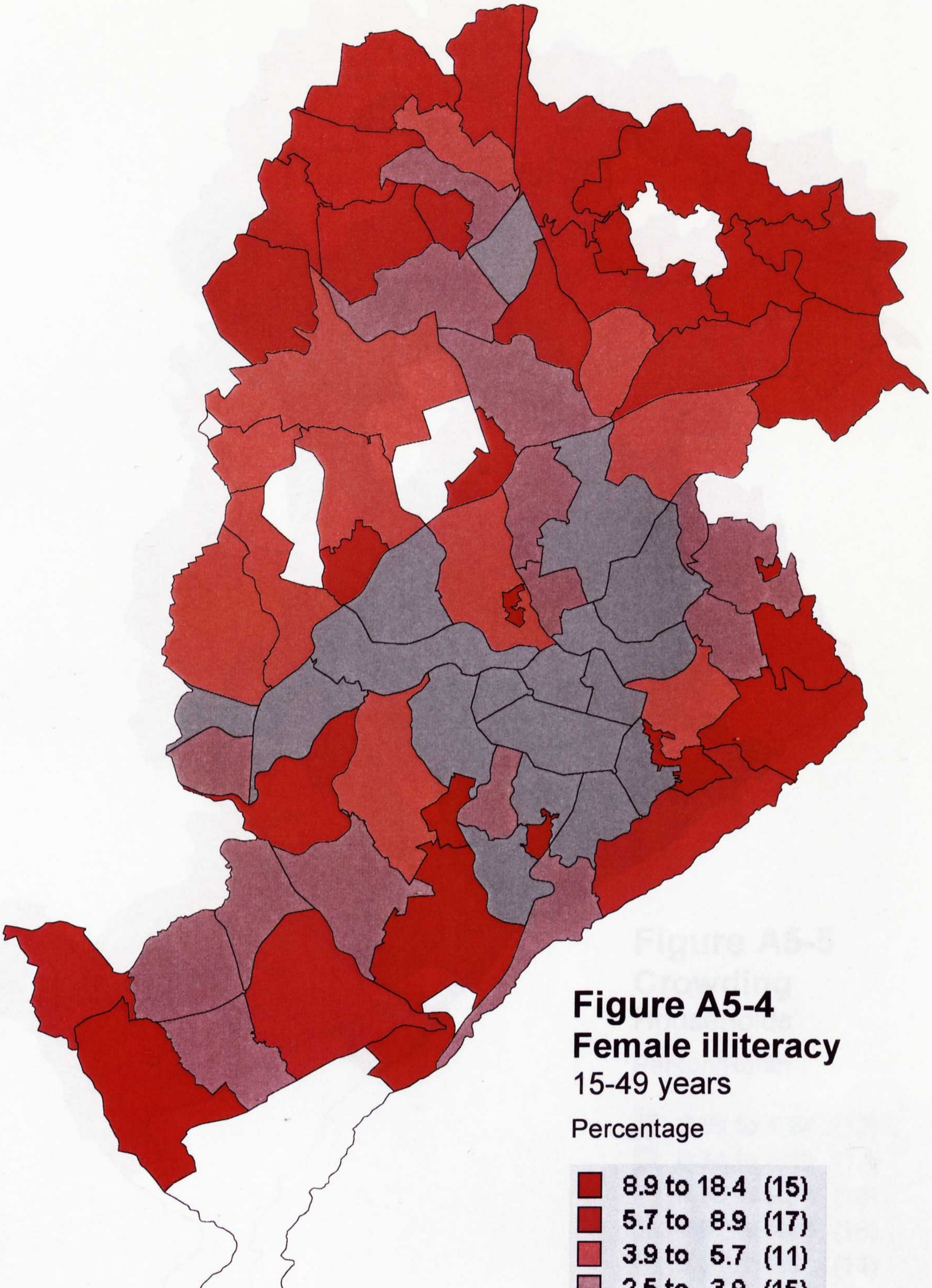

Figure A5-4
Female illiteracy
15-49 years

Percentage

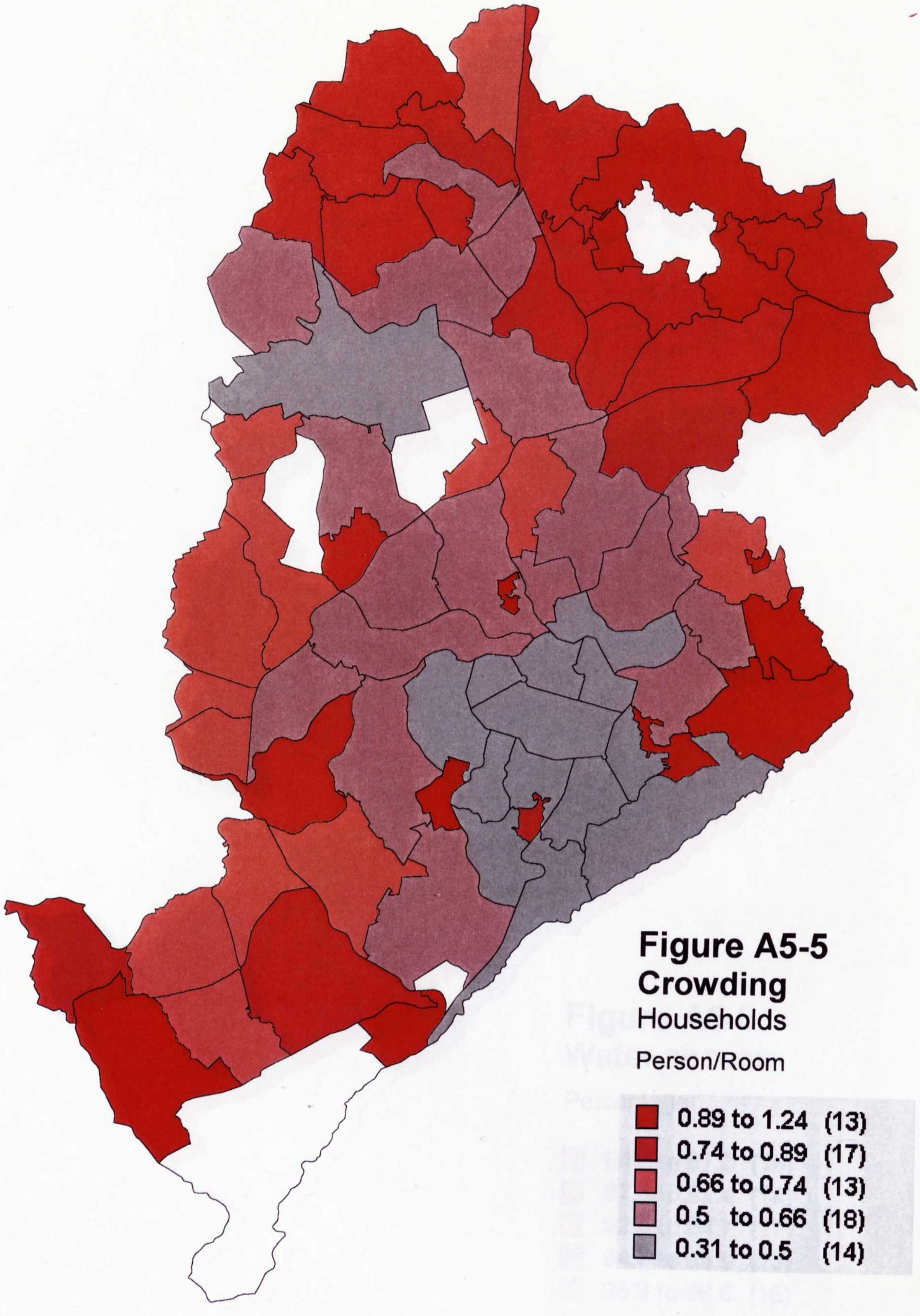
Figure A5-5
Crowding
Households
Person/Room
0.89 to 1.24 (13)
0.74 to 0.89 (17)
0.66 to 0.74 (13)
0.5 to 0.66 (18)
0.31 to 0.5 (14)

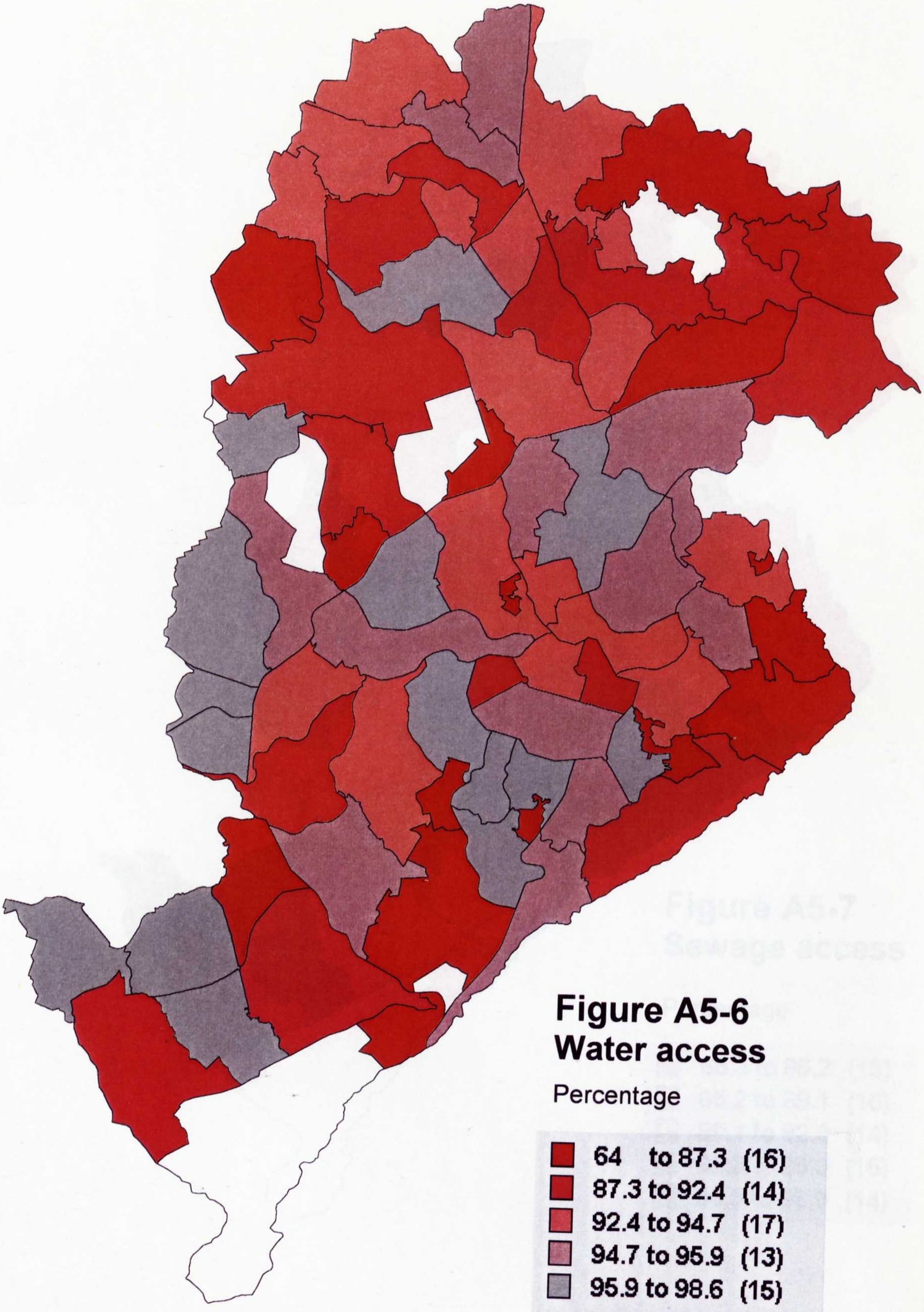

Figure A5-6
Water access

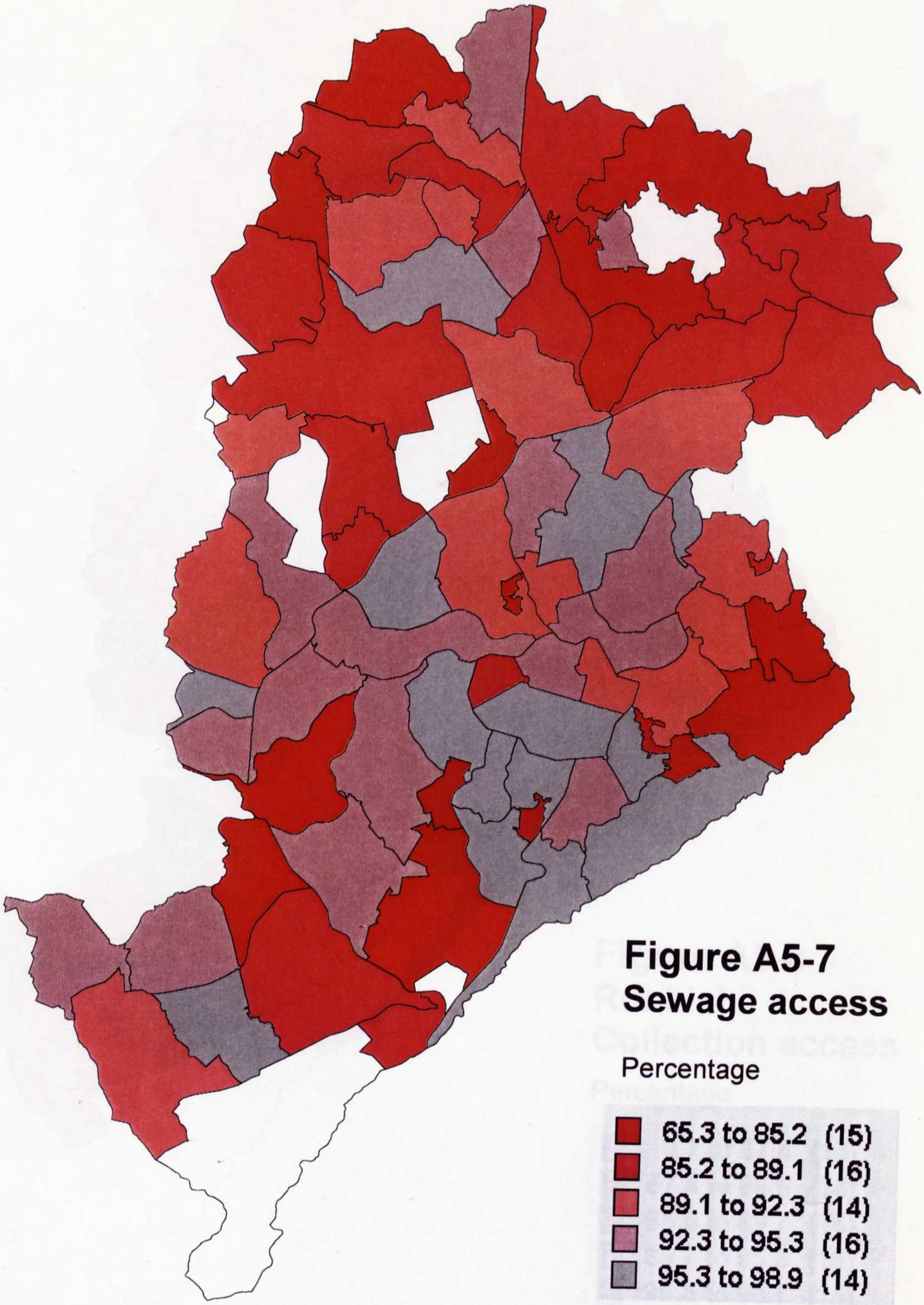

Figure A5-7
Sewage access

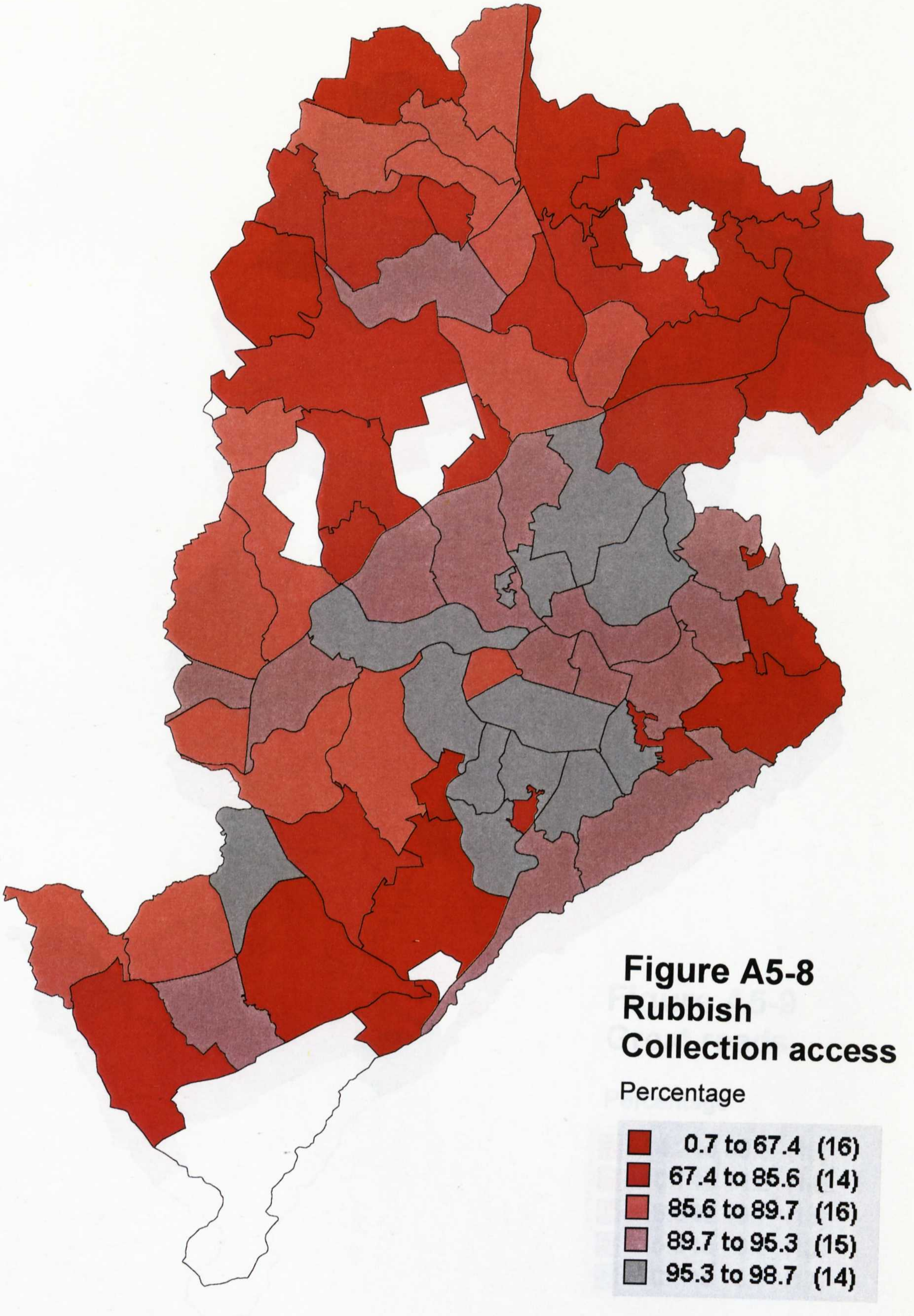

Figure A5-8
Rubbish Collection access

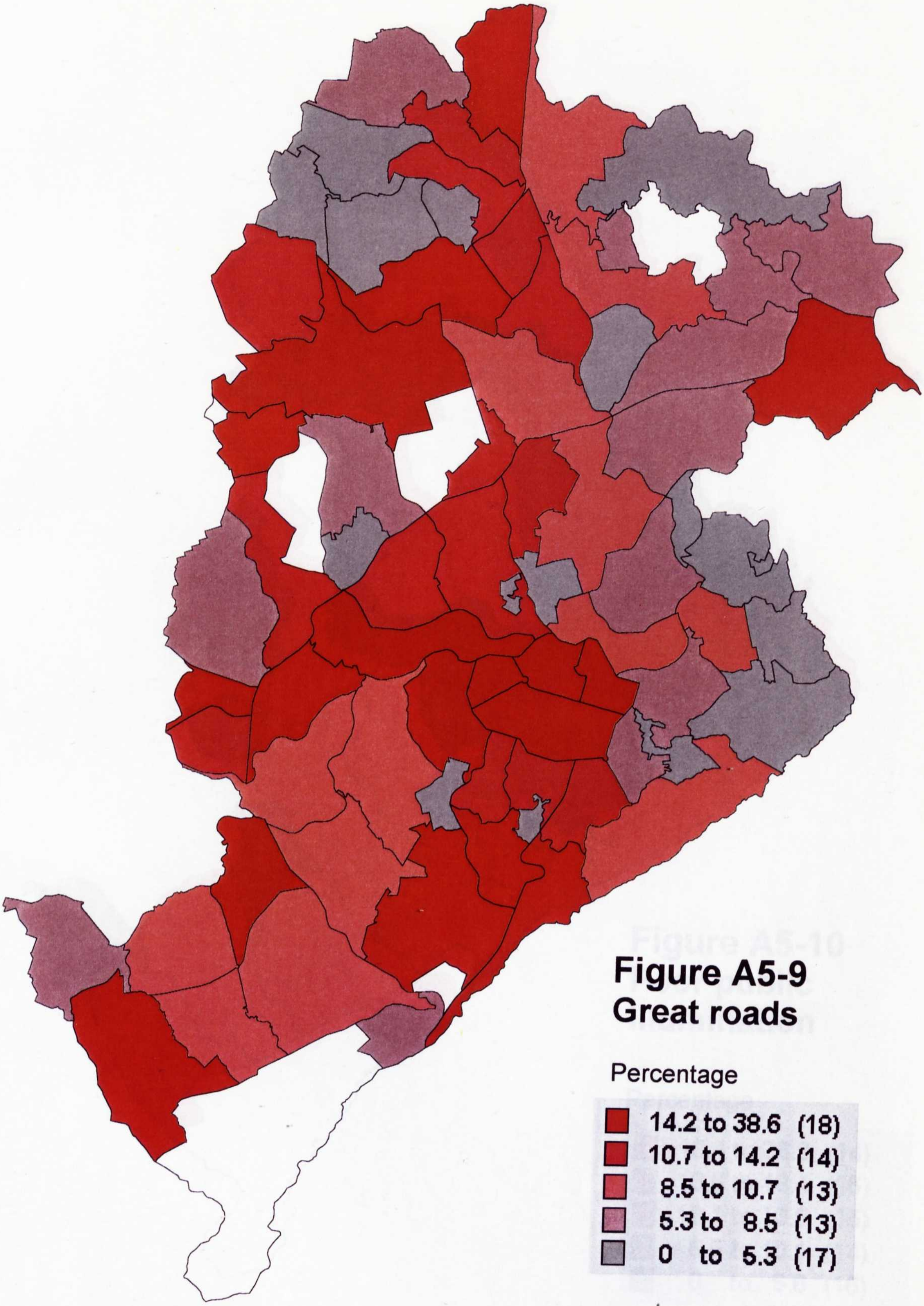

Figure A5-9
Great roads

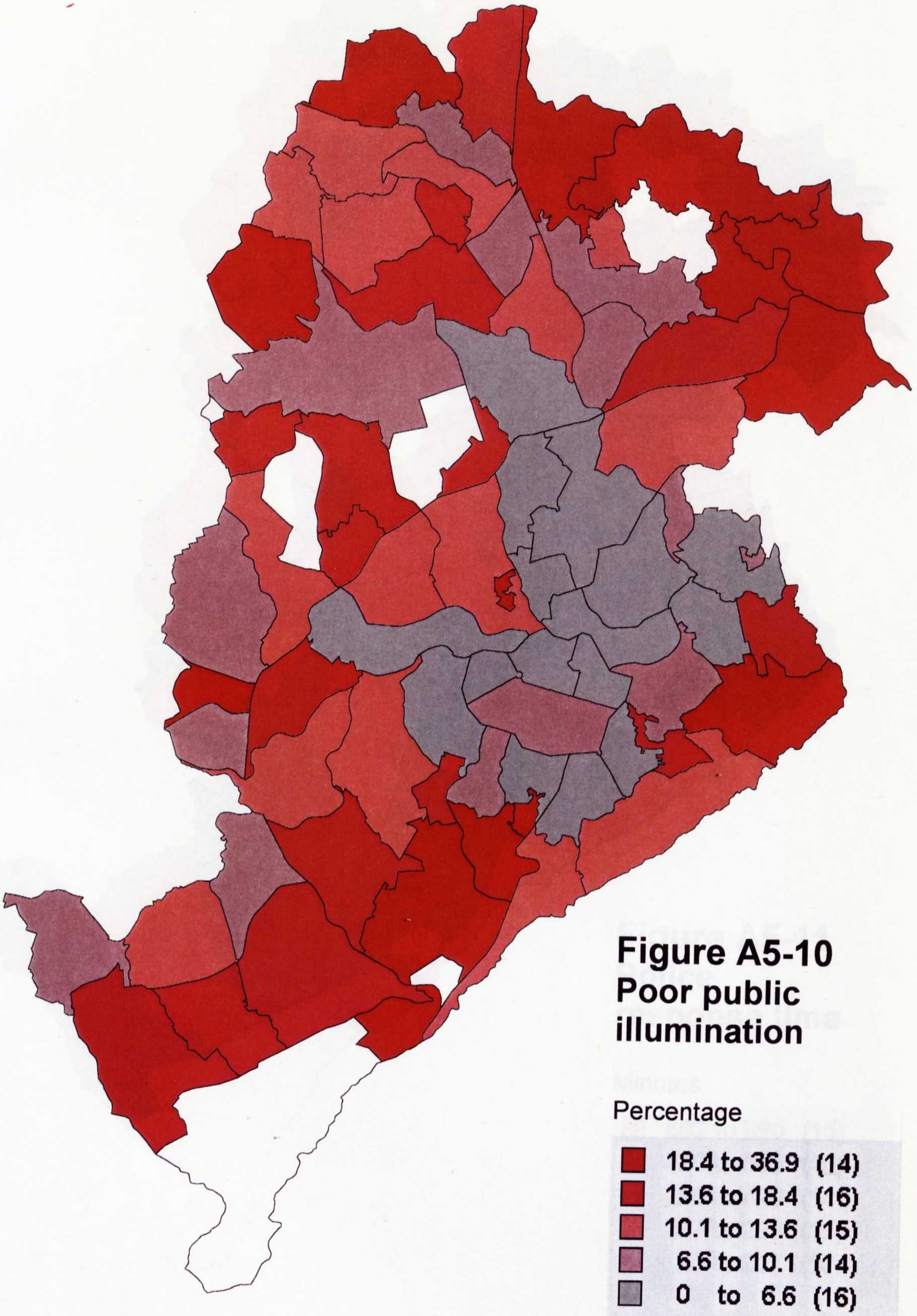

Figure A5-10
Poor public illumination

Percentage

■	18.4 to 36.9	(14)
■	13.6 to 18.4	(16)
■	10.1 to 13.6	(15)
■	6.6 to 10.1	(14)
■	0 to 6.6	(16)

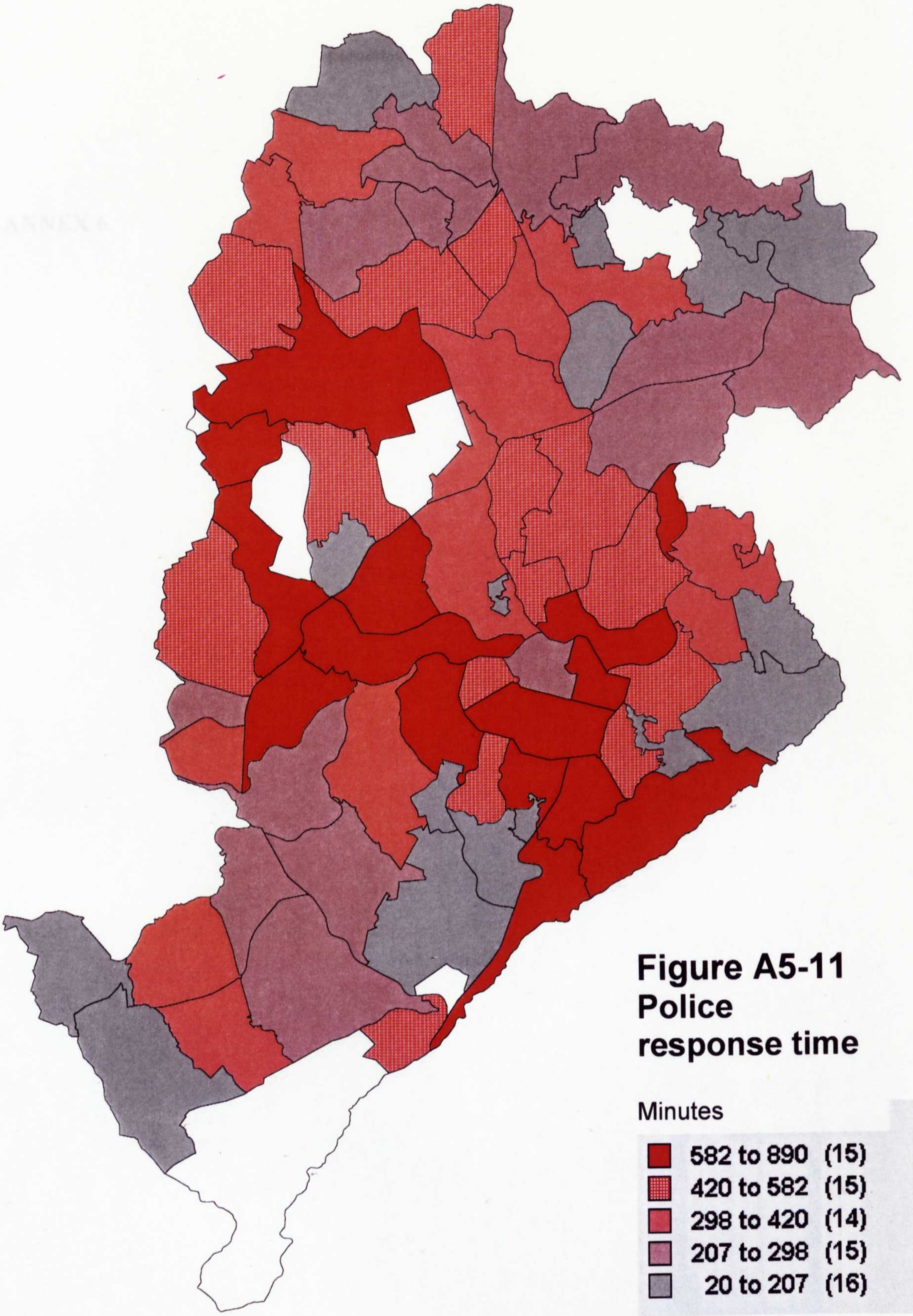

Figure A5-11
Police response time

ANNEX 6

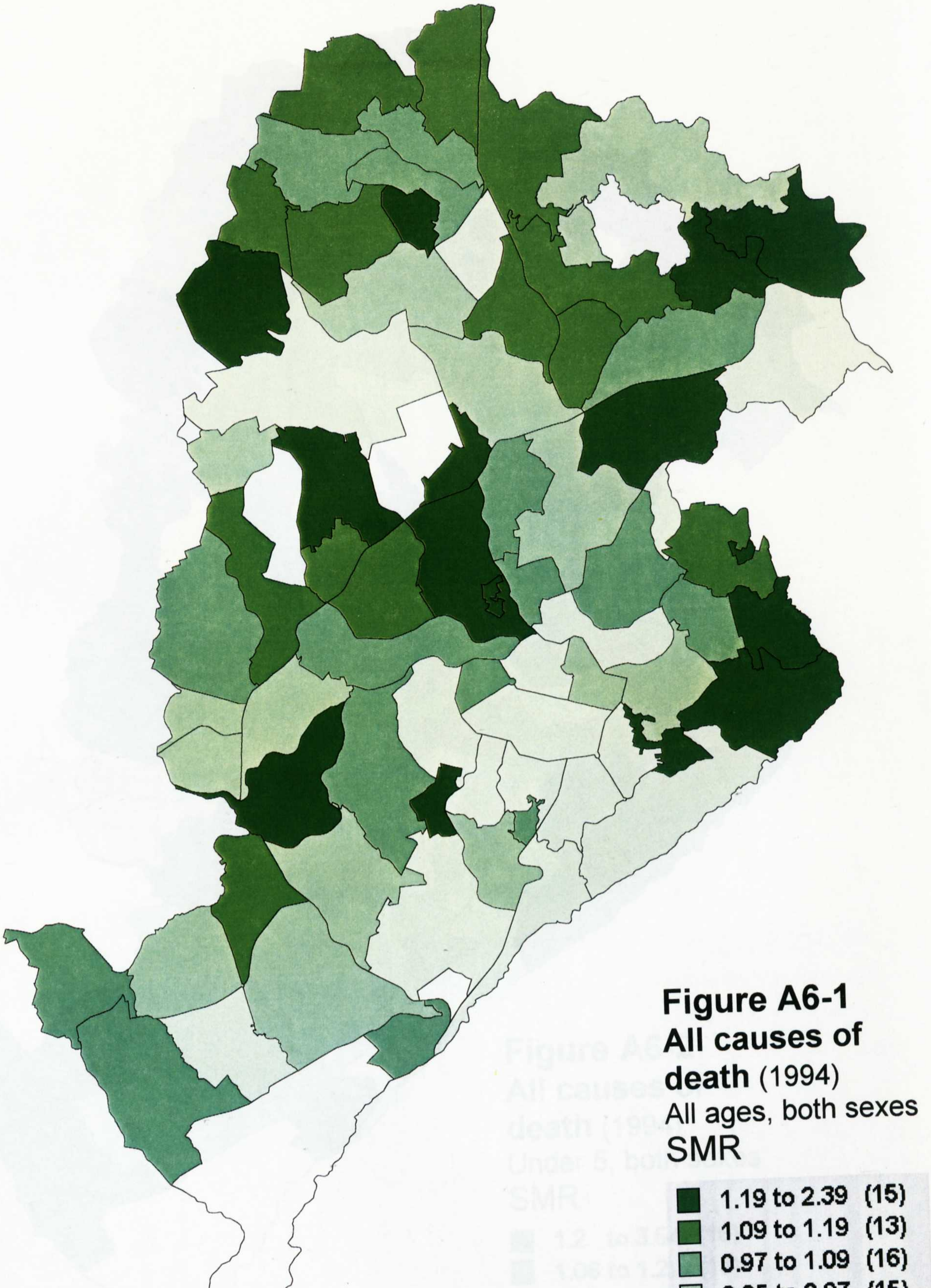

Figure A6-1
All causes of death (1994)
All ages, both sexes
SMR

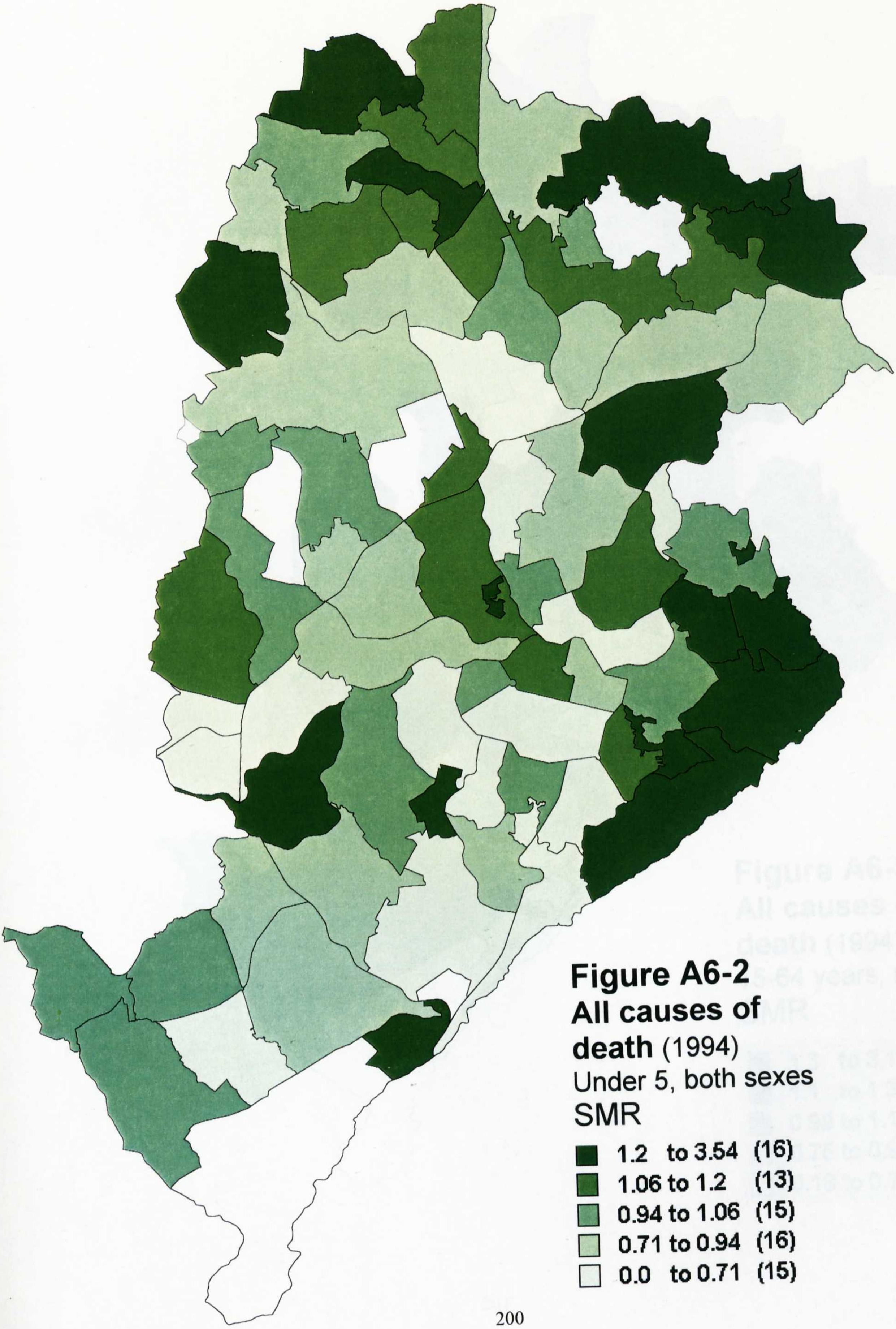

Figure A6-2
All causes of death (1994)
Under 5, both sexes
SMR

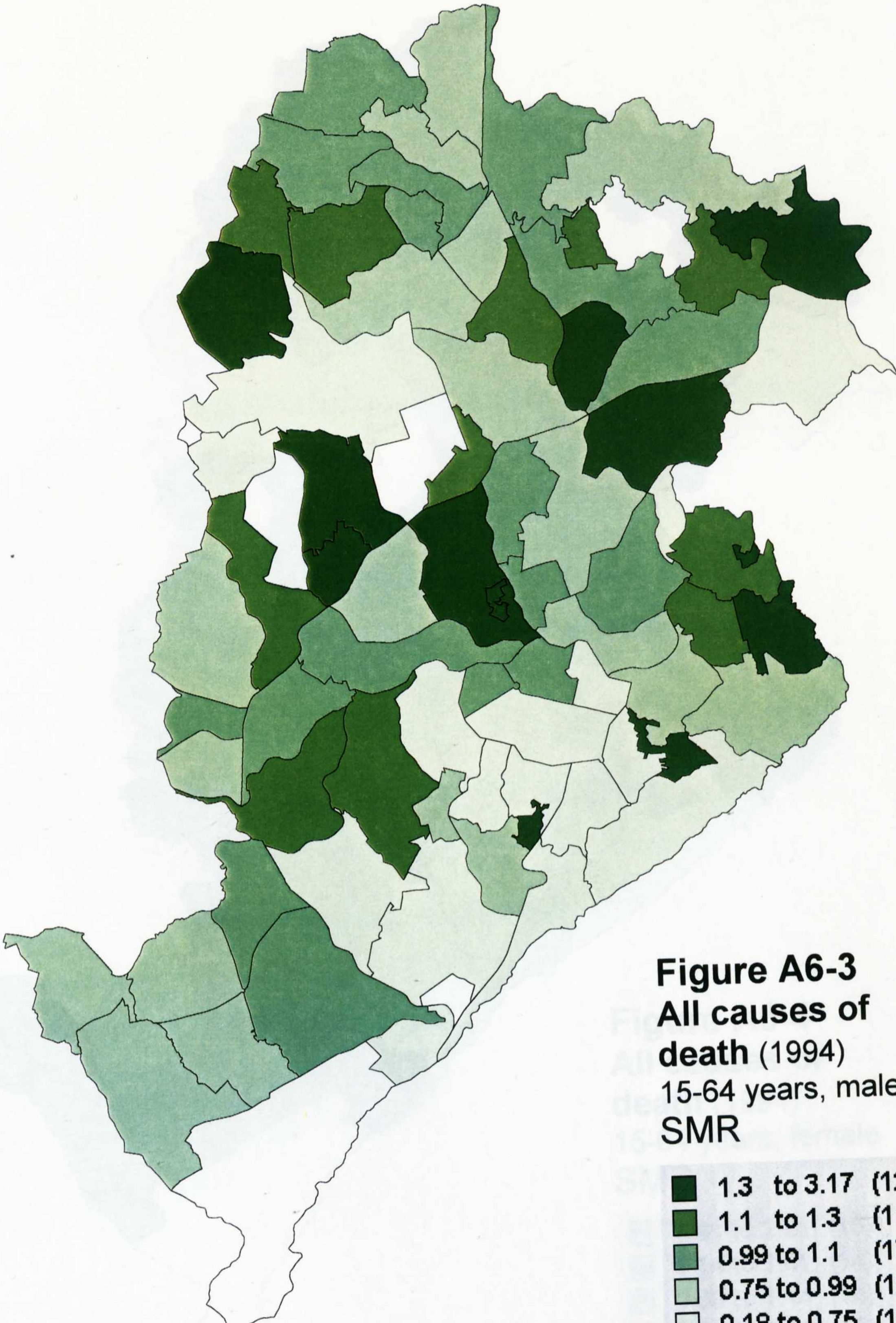

Figure A6-3
All causes of death (1994)
15-64 years, male
SMR

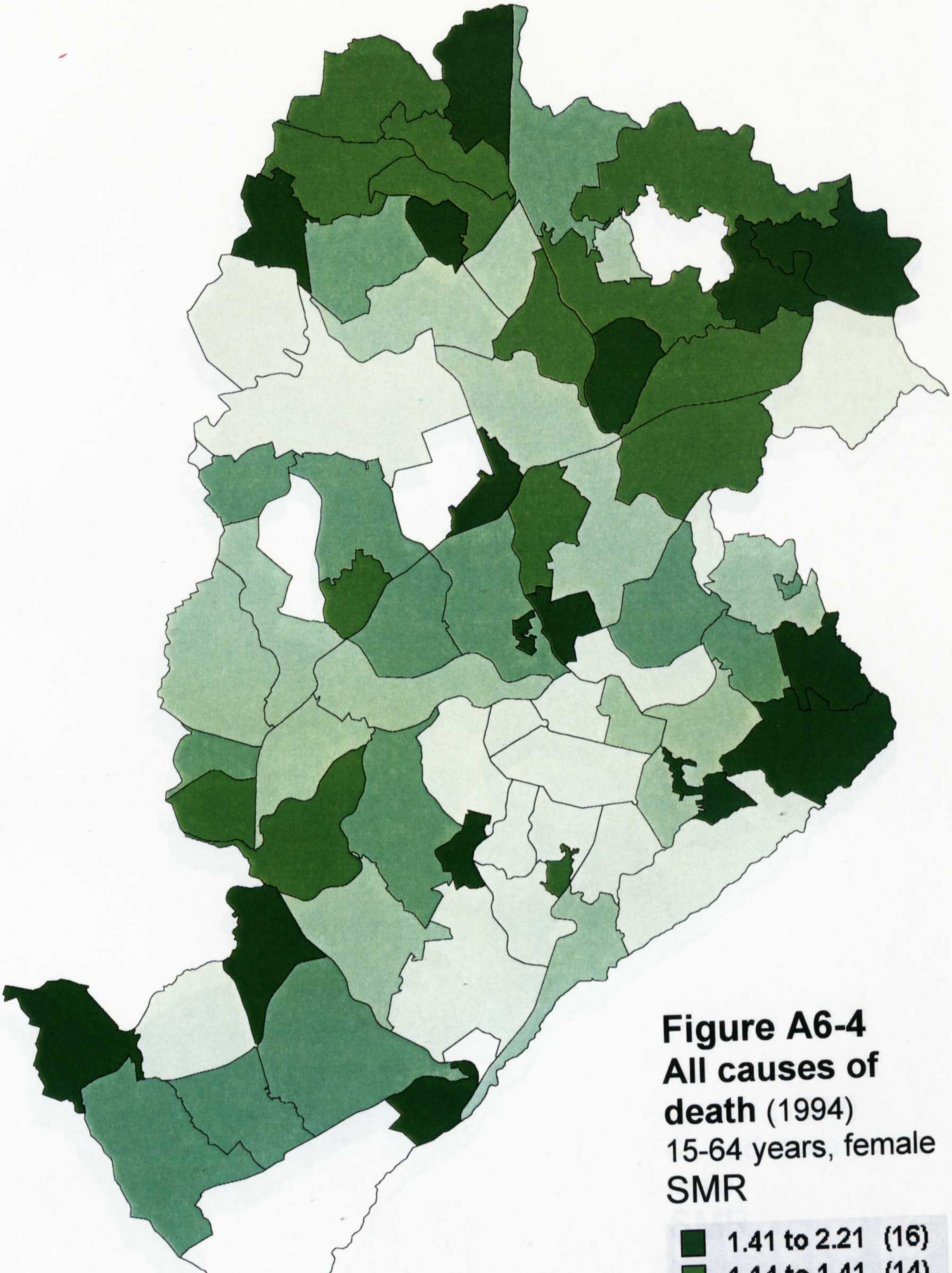

Figure A6-4
All causes of death (1994)
15-64 years, female
SMR

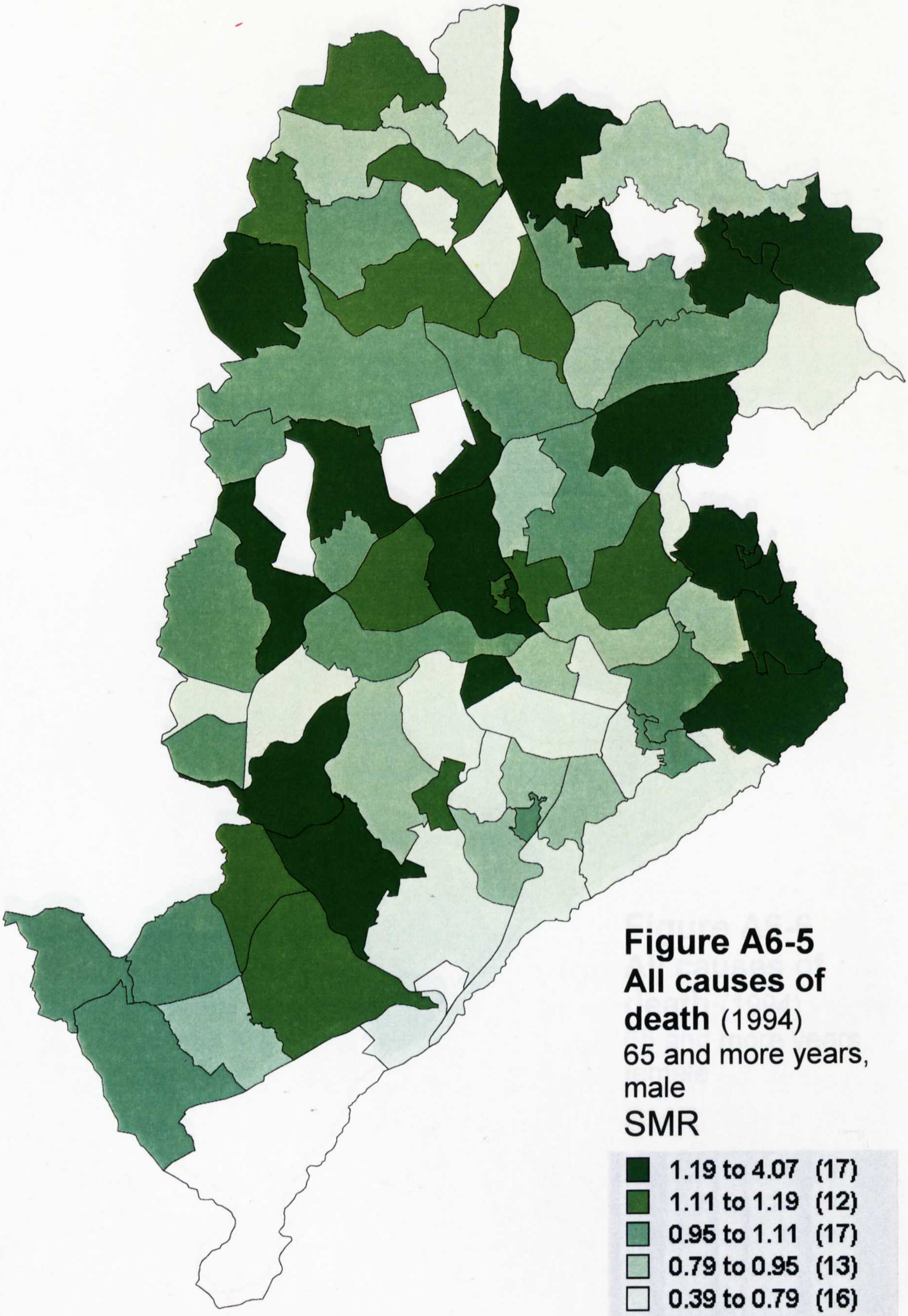

Figure A6-5
All causes of death (1994)
65 and more years, male
SMR

1.19 to 4.07	(17)
1.11 to 1.19	(12)
0.95 to 1.11	(17)
0.79 to 0.95	(13)
0.39 to 0.79	(16)

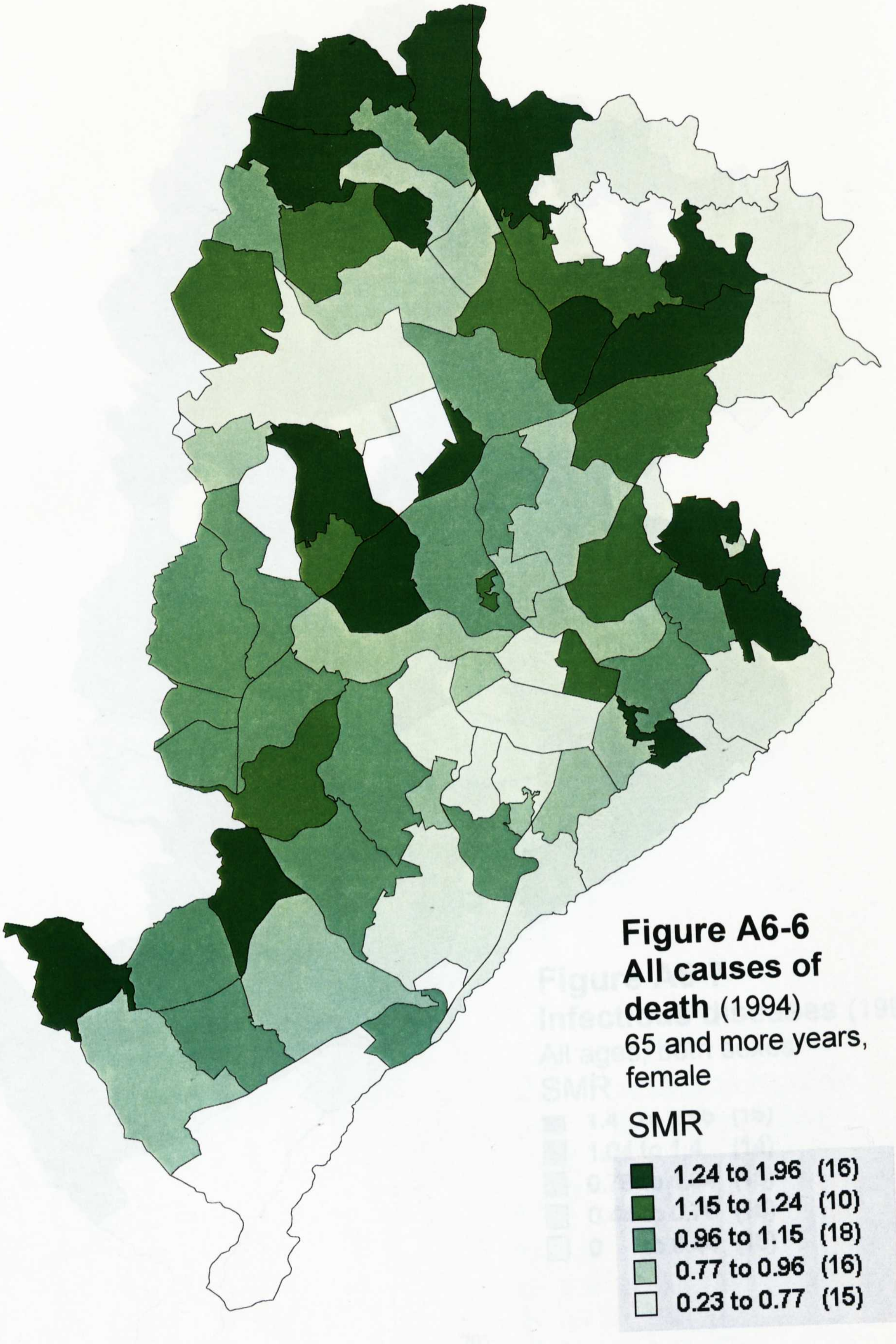

Figure A6-6
All causes of death (1994)
65 and more years, female

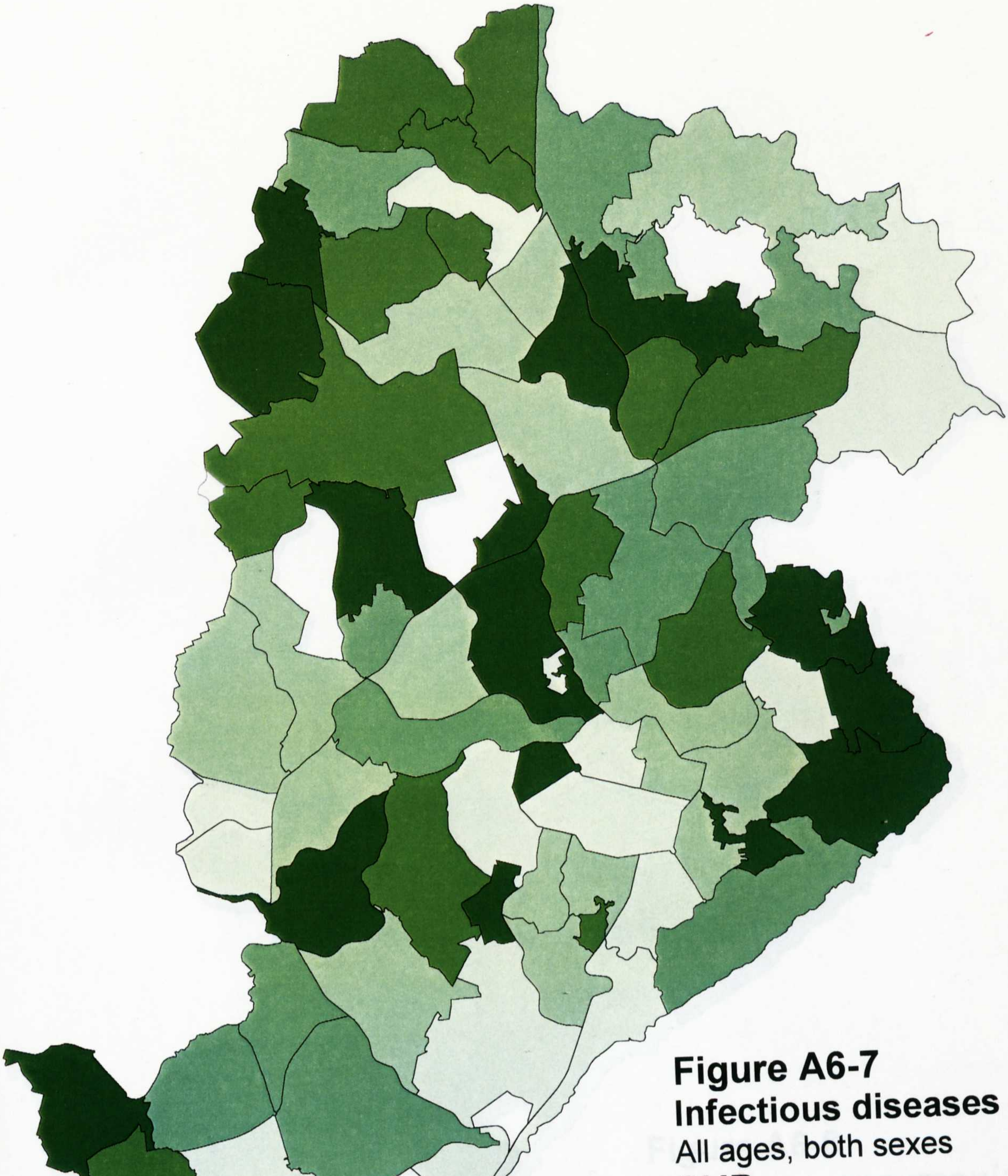

Figure A6-7
Infectious diseases (1994)
All ages, both sexes

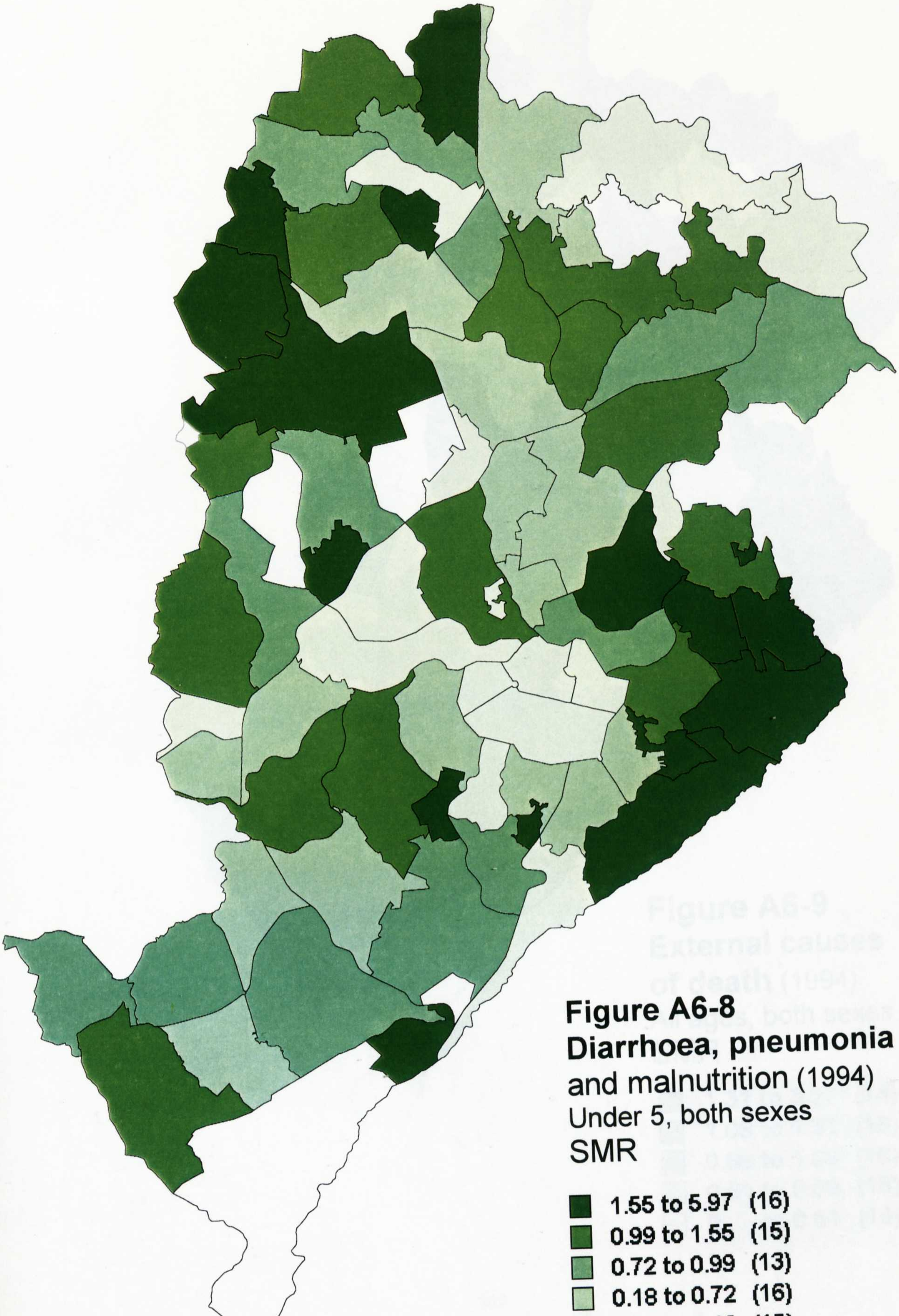

Figure A6-8
Diarrhoea, pneumonia
and malnutrition (1994)
Under 5, both sexes
SMR

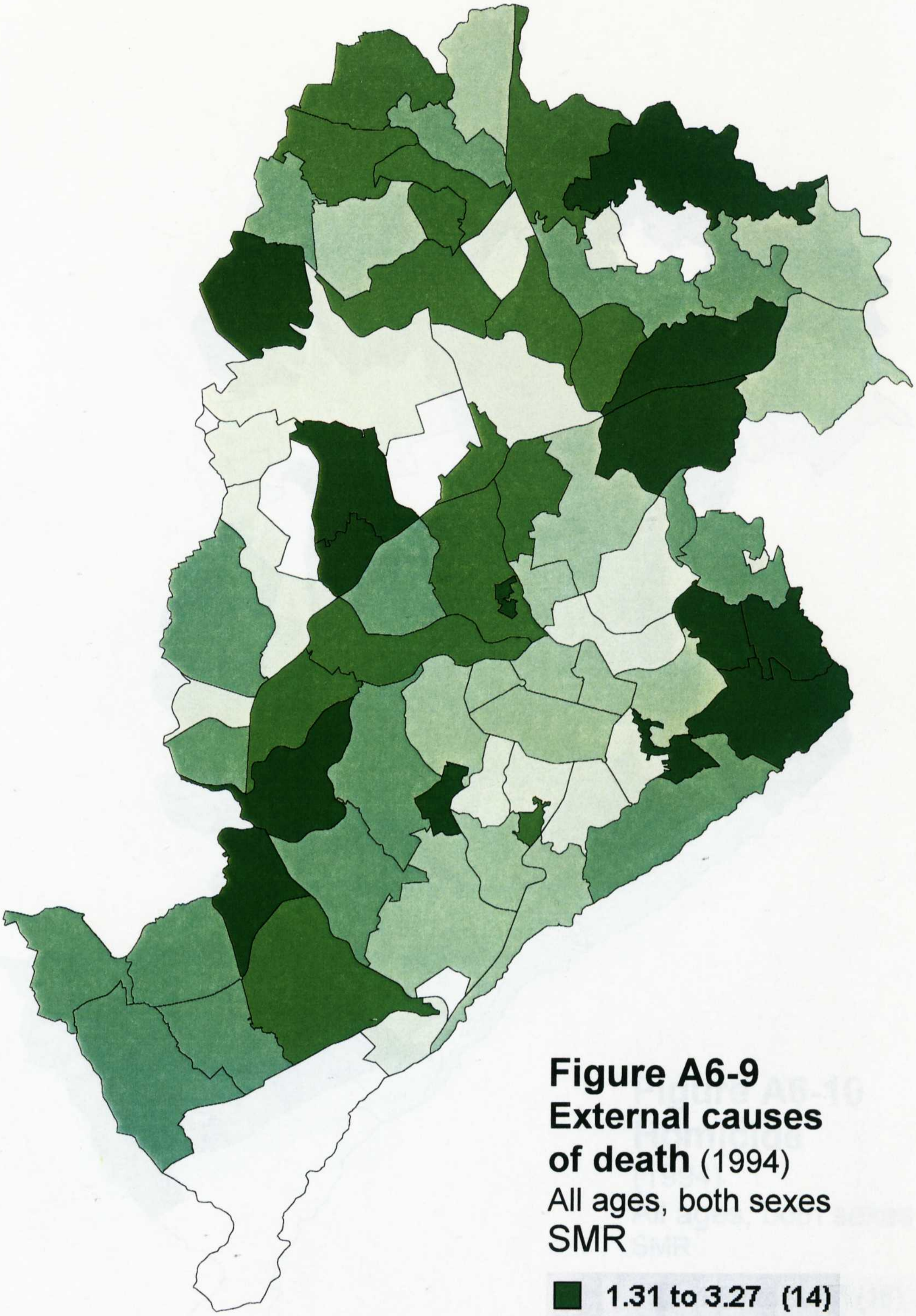

Figure A6-9
External causes of death (1994)
All ages, both sexes
SMR

■	1.31 to 3.27	(14)
■	1.08 to 1.31	(15)
■	0.89 to 1.08	(16)
■	0.61 to 0.89	(15)
□	0 to 0.61	(15)

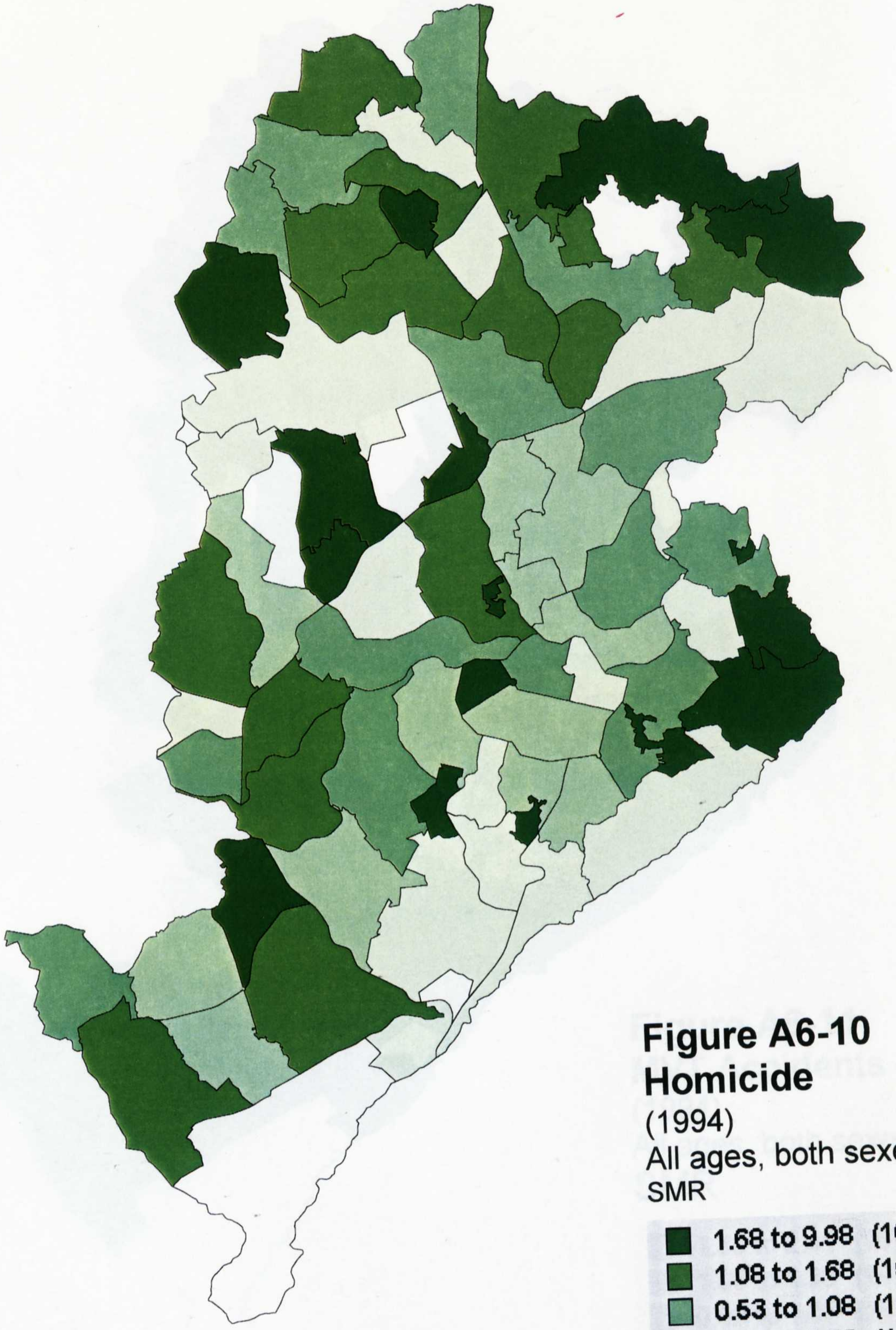

Figure A6-10
Homicide
(1994)
All ages, both sexes
SMR

1.68 to 9.98	(16)
1.08 to 1.68	(15)
0.53 to 1.08	(15)
0.22 to 0.53	(12)
0 to 0.22	(17)

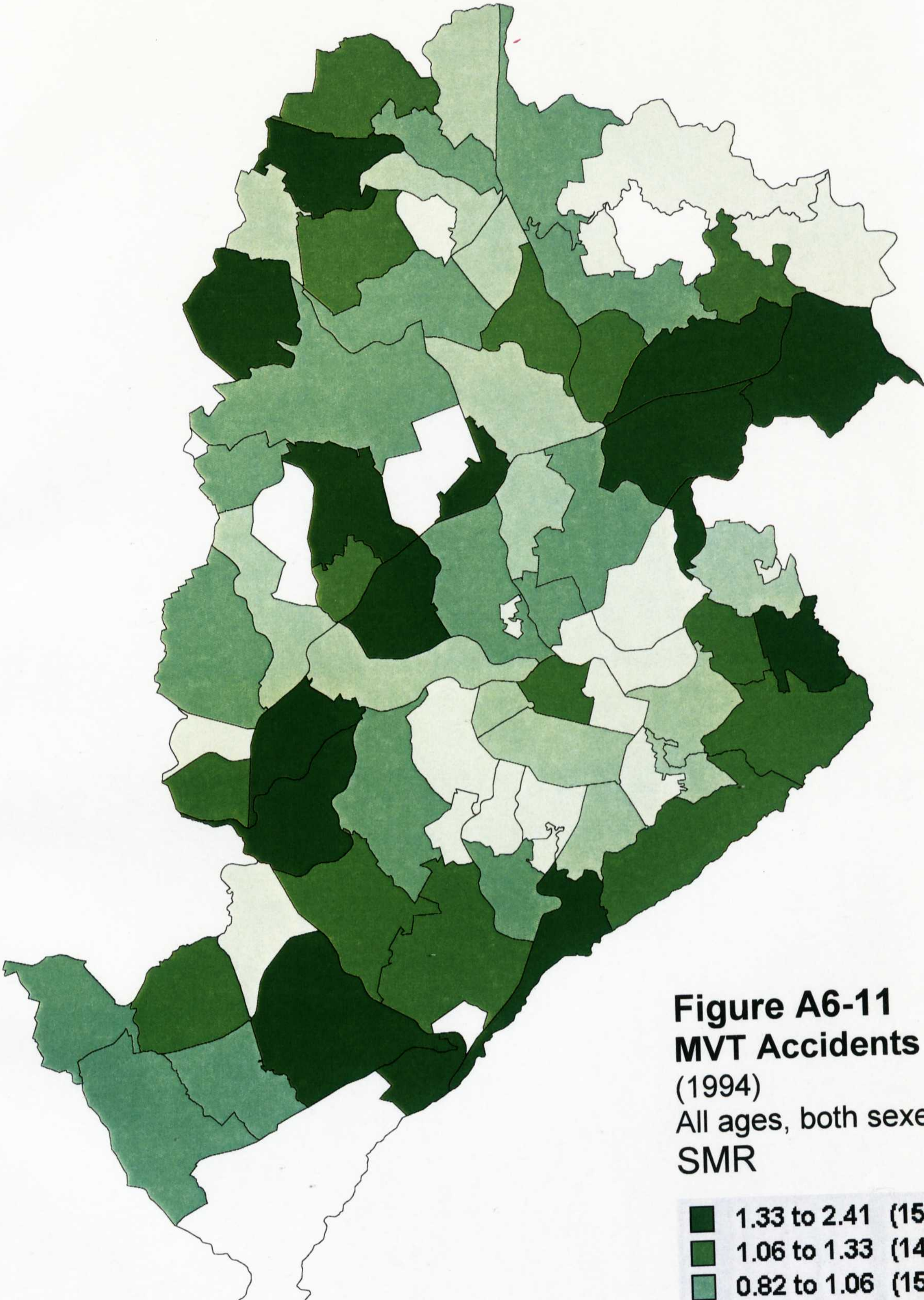

Figure A6-11
MVT Accidents
(1994)
All ages, both sexes
SMR

1.33 to 2.41	(15)
1.06 to 1.33	(14)
0.82 to 1.06	(15)
0.59 to 0.82	(14)
0 to 0.59	(17)