

The spatial distribution of injury burden of children in the western geographic service area,
City of Cape Town (2011-2015)

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Plagiarism Declaration

I, Zulfah Albertyn-Blanchard, hereby declare that the work on which this thesis is based is my original work, (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed:

Date: 10 February 2022

List of Abbreviations

- AIC: Akaike information criterion
- CDC: Centres for Disease Control and Prevention
- CDR: Child Death Review
- CoCT: City of Cape Town
- COD: Cause of death
- CSA: Childsafe South Africa
- DALYs: Disability-adjusted life years lost
- FPS: Forensic Pathology Services
- GIS: Geographic information systems
- HICs: High-income countries
- ICD-10: International Classification of International Diseases
- IMS: Injury Mortality Survey
- LMICs: Low-middle-income countries
- MDGs: Millennium Developmental Goals
- NB: Negative binomial
- NIMSS: National Injury Mortality Surveillance System
- RCCH: Red Cross War Memorial Children's Hospital
- RTC: Road traffic crash
- SAIMD: South African Index of Multiple Deprivation
- SANRAL: South African National Roads Agency LTD
- SAPS: South African Police Service
- SDGs: Sustainable Development Goals
- SES: Socio-economic status
- SRM: Salt River Medico legal mortuary
- STATSSA: Statistics South Africa
- UNCRC: Convention on the Rights of the Child
- UMICs: Upper-middle-income countries
- US: United States
- VPUU: Violence Prevention through Urban Upgrading
- WHO: World Health Organization
- WGS84: World Geodetic System 1984
- YLD: Years of life lived with disability
- YLL: Years of life lost

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Abstract

Background:

Child injury is a major global public health concern with accounting for nearly 300,000 deaths annually and non-fatal injuries resulting in long or short - disabilities. Young children are more likely to be involved in a non-fatal injury than adolescents, who are more likely to be involved in a fatal injury. Males are likely than females to suffer from a fatal or non-fatal injury. The likelihood to be injured has a spatial dimension with impoverished areas more likely to report injuries among adults and children compared to well-resourced areas. This differentiation is driven by inequality and social determinants which impacts the likelihood of implementing appropriate infrastructure and services to prevent these incidents, particularly in children. South Africa displays similar trends in the childhood injury pattern and the risks attributed to this burden.

Method:

This thesis retrospectively assesses the injury burden experienced by children aged 17 years and younger between 2011-2015 in the City of Cape Town (CoCT). Using routine mortuary data from Salt River Medico-legal Mortuary (SRM) across four sub-health districts of the CoCT namely Klipfontein, Mitchells Plain, Southern, and Western; the injury profile of children will be examined. The child death review (CDR) data will be used to determine the mortality profile of children aged 17 years and under. The Childsafe data will be used to determine the morbidity profile for children under 13 years, specifically RTCs.

Exploratory analysis is used to describe demographic variables and create a heat map, and choropleth map of injury mortality, prior to a risk assessment of gender relative to various explanatory variables. Regression models adjusted for age, gender, time of day, and injury severity determined the likelihood of hospital admission for RTC injuries. Spatial regression models identified socioeconomic and geographical variables that influenced transport-related injury mortality.

Findings:

This thesis found that more than 50 % of child injury deaths were unintentional (51.2%) across all age groups. Older male children (aged 15-17 years) mostly died from homicide, particularly

due to sharp force injuries. This is the first study to report that most child injury deaths were located in the Klipfontein sub-health district, Nyanga has the highest prevalence (give %) , with homicides more likely than any other form of injury death among children. We found that the injury mortality pattern for children differs dependent on their age, highest among Most transport-related deaths occurred during daylight hours across all age groups. Utilising a heat map, cluster, and spatial regression analysis, this thesis found that Nyanga as the most deprived township also had the most transport-related injuries. Children aged 5-9 years contributed to the highest RTC premature mortality and non-fatal RCT incidents compared to other age groups. Males are more likely to be involved in both a fatal or non-fatal pedestrian RTC incident compared to females. Hospital admittance followed by a non-fatal RTC incident was mainly reported in children aged 5-9 years compared to any other age group and was more likely to occur during afternoons or evenings over the weekend.

Conclusion:

Injuries are one of the leading causes of mortality and morbidity among children living in the CoCT, South Africa. This thesis provides insights to identify high-risk child populations through the use of a spatial conceptual framework the findings highlight factors that Increase risk for Injuries such as deprived suburbs, and the speed limit of the road, which has not been explored in other studies . This research highlights that children of a certain age are more vulnerable than others, especially males living in low socio-economic areas. There is an urgent need for more sustainable and representative national injury surveillance to be integrated with routine health information systems. The monitoring of child injury mortality in South Africa needs to be strengthened.

Chapter 1: Introduction

1.1 Background

Globally, child injury is a major public health concern accounting for nearly 300,000 deaths annually (Institute for Health Metrics and Evaluation, 2021; Kassebaum et al., 2017), with most childhood injury deaths due to road traffic crashes (RTC), followed by drowning, falls and homicide (Institute for Health Metrics and Evaluation, 2021). Since 1990, global fatal RTCs among children have been declining, with a similar pattern reported for drowning and homicides among children (Institute for Health Metrics and Evaluation, 2021).

Injuries not only cause death but also result in short-term and lifelong disability. In 2019, the estimated non-fatal injuries accounted for nearly 126 years lived with disability (YLDs) per 100,000 children, with falls, RTC and homicide contributing to most non-fatal injuries (Institute for Health Metrics and Evaluation, 2021). Historically, the global non-fatal fall injury pattern has remained stable since 1990, while the pattern of fatal RTCs and homicides has increased over the last three decades (Institute for Health Metrics and Evaluation, 2021).

Geography, where children live, is an important factor influencing a child's injury risk. Low and middle-income countries (LMICs) report more than 50% of the total injury burden for children globally (Institute for Health Metrics and Evaluation, 2021), with falls leading the non-fatal injury burden for children, followed by RTCs and homicides (Institute for Health Metrics and Evaluation, 2021). The burden for fatal child injury deaths in LMICs is also different to the global fatal injuries burden, with drowning the leading cause of injury mortality, followed by RTCs and homicide for children (Institute for Health Metrics and Evaluation, 2021). The WHO estimates that between 1997 and 2012, global child homicides declined by 15% and RTCs by 10% (Institute for Health Metrics and Evaluation, 2021). This reduction has been driven by a substantial decline of 61% and 29% in RTCs and homicides respectively in high-income countries, with a smaller decline of 36% in RTCs and 1% in homicides reported in LMICs (Institute for Health Metrics and Evaluation, 2021).

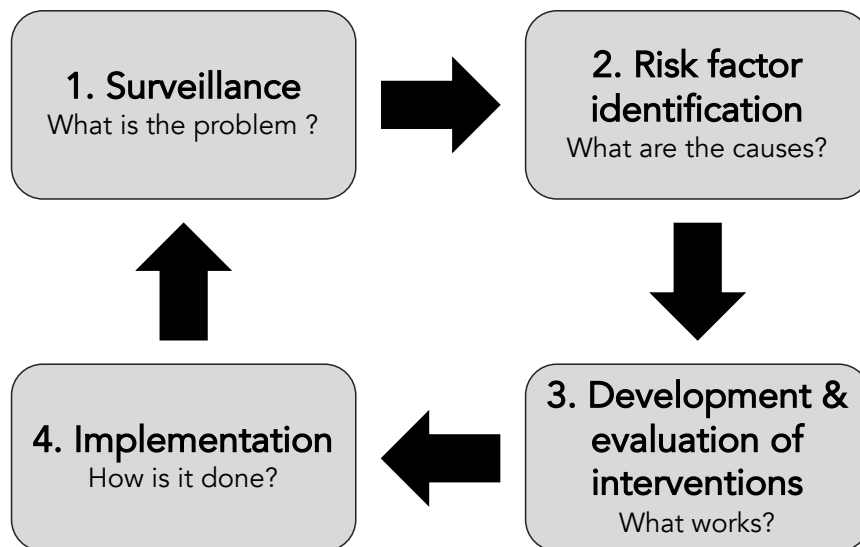
In South Africa, the 2012 BoD study reported that homicide was the eighth leading cause of death (COD) with RTCs ninth for children younger than 14 years (Pillay-van Wyk et al., 2016). However, according to the Road Traffic Management Corporation (2020), the rate of RTC

deaths involving children has reportedly declined in South Africa . In 2017, it was reported that there were 7 RTC deaths per 100,000 children aged 0 to 14 years compared to approximately 13 RTC deaths per 100, 000 in 2009 (Matzopoulos et al., 2015; Prinsloo et al., 2021). However, these rates remain higher than the reported global average of 5 RTC deaths per 100,000 children aged 0 to 14 years in 2019 (Institute for Health Metrics and Evaluation, 2021). The decline in RTCs in South Africa can be attributed to an improvement in appropriate road infrastructure and an increase in enforcing road rules. Similarly, an analysis of South African Police Service (SAPS) data for child homicide from 2013-2016, shows a decline of the child homicide rate by 9% between 2009 and 2017 (Delaney & Hall, 2018). When compared to child abuse and neglect which have declined over this period, child homicides that are unrelated to child abuse and neglect increased from 3 homicides per 100,000 population to 4 homicides per 100,000 population (Delaney & Hall, 2018). This still shows that the child homicide rate in South Africa is nearly twice the global average of 2 child homicide deaths per 100,000 children aged 0 to 14 years (World Health Organization, 2020).

The magnitude of the injury burden, including its frequency, severity, life-long disability and death, has compelled society to put preventative measures in place.(Dobson, 2020; Yanchar et al., 2012). Figure 1.1 highlights the public health approach to injury prevention. The first step involves identifying what the problem is, followed by highlighting the risks associated with the injury, then developing and evaluating which interventions work and finally implementing the intervention (Peden, 2008). This approach is non-linear but iterative in nature.

Figure 1.1

Public health approach to injury prevention adapted from Peden et al., 2008



Mortality is a criterion often used to understand the severity of an injury, but this is just a tip of the iceberg. The WHO proposes a public health approach to prevent injuries in a systematic way (Peden, 2008). This approach not only focuses on the individual factors but also on environmental contexts that may result in injuries. Before preventing new injuries, it is important to first understand the injury burden through surveillance programmes (Peden, 2008). To reduce the severity of injuries and decrease the frequency and disability following an injury, we must first understand the cause of the injuries, highlight the most impactful interventions and finally consider how these interventions might be implemented (Peden, 2008). These child injury burden preventative measures have various strengths. With a longer implementation, the most successful initiatives have been shown to include an educational component that involves active learning with parental involvement (Zare et al., 2019). Studies have found that these two components result in positive injury outcomes like improved road safety behaviour among 7-year-olds crossing the street (Zare et al., 2019).

1.2 Child Injury in the Context of South Africa

In the last decade, child injury rate in South Africa has remained unchanged, with an estimated 31 injury deaths per 100,000 children aged 0 to 14 years reported from 2009 to 2017 (Matzopoulos et al., 2015; Prinsloo et al., 2021). Child injury in South Africa is a public health concern, particularly RTCs, drowning and homicide. South Africa's political history plays a

significant role in the injury burden experienced by children today. During the apartheid era, segregation laws led to forced removals of individuals based on race to areas that were impoverished and under-served, leading to poor health outcomes due to poor infrastructure and lack of health facilities and social services. This resulted in townships plagued by high rates of unemployment, poverty, poor housing, poor quality of education, and limited job opportunities; increasing the likelihood of a child being injured (Swart et al., 2012; Van As & Dhai, 2017). Other risk factors include poor supervision; inadequate infrastructure, such as poor roads; and lack of enforcement of road rules.

The second burden of disease study of South Africa utilised death notification data for all mortuaries between 1997 and 2012 from Statistics South Africa (STATSSA), found that the biggest proportions of child injury deaths were among children younger than 5 years and those aged 15 years and older (Pillay-van Wyk et al., 2016). However, in this PhD study, different age groupings were used for older children (15 to 17 years), making direct comparison with the BoD study difficult as there is an attempt to use the definition of a child as defined by the United Nations (Unicef). This is important as those individuals older than 17 years may have a different risk profile compared to children aged 0 to 17 years, which could mask the factors pertinent to children. Younger age groupings from 1 to 14 years are comparable for both studies.

1.3 Injury Surveillance

South Africa has excellent vital registration data systems compared to other African countries. There has been an improvement in death registration coverage since 1998, with nearly 80% of deaths being registered as of 2007 (Bradshaw et al., 2010). However, STATSSA continues to classify 70% of non-natural deaths as other external accidental injuries or undetermined intent (Statistics South Africa, 2021). However, there are several projects underway to improve the national collection and management of death notification to increase the accuracy of the COD (Bradshaw et al., 2020). This also has a bearing on the analysis of child injury data as it is usually hidden among adult injury data, and the data is not disaggregated by age categories from a children's perspective. Most reports only represent child injury data for children aged 0 to 4 years and 5 to 14 years, excluding children aged 15 to 17 years who are generally placed in the 15 to 19-years-old age group. Even though globally this age group is viewed as being part of adolescence, it does contribute to an underestimation of the overall child injury burden.

1.3.1 Injury Mortality Statistics

Mortality statistics are recorded as mortality rates, leading COD, apparent manner of death, and YLL (Lopez, 2005), and are extracted at the country level from vital registration data that records the deaths and births of a population. If an individual dies, a death certificate is completed with specific information relating to the underlying COD. The COD is then captured and stored on the vital registration system. Despite this process appearing to be simple, straightforward, and a requirement by law, only HICs and a few middle-income countries prioritise the system and ensure the collection of timely and accurate data (Organization, 2010; World Health Organization, 2010). A vital registration system is useful for recording accurate information about the cause of death (COD), age, and gender of a deceased person. This is because the information is recorded by a pathologist for unnatural causes and a general practitioner for natural causes, and the death certificate is captured and stored on a central database. South Africa's vital death registration system is efficient, however, completing the death notification form with the correct COD information is not always accurate. The South African Medical Research Centre implemented a training program for general practitioners to improve their ability to complete the COD on death notification forms, as they had received insufficient training in this area (Groenewald P, 2020). A validation study of this training program found that when doctors were trained to on how to include correct COD information on the death notification, the quality of COD information improved (Bradshaw D et al., 2020). This has improved the burden of disease estimates, especially for injuries. Furthermore, the coding of COD has its limitations, especially for injuries, due to the possibility of issues arising with the International Classification of Diseases -10 (ICD-10) (World Health Organization, 2016) coding (Lopez, 2005). The ICD-10 coding system classifies COD and is predominately used when mortality-related indices are recorded (World Health Organization, 2016). Mortality-related indices can be derived from several other reliable sources, such as forensic pathology post-mortem reports, medical and police reports, verbal autopsy, and traffic crash reports (Segui-Gomez & Hyder, 2011). Besides a verbal autopsy interview, police data can also be collected to gather information about the circumstances surrounding the injury; however, this information is only available once the investigation has been completed and there is a judicial outcome. Although police data is sometimes incomplete and fails to provide an accurate COD, it can provide information regarding the circumstances of the death, such

as whether the death was intentional or unintentional and the mechanism of death (Gould et al., 2012).

1.3.2 Assessing the Quality of Injury Data

Monitoring child injury mortality is important for injury prevention and management of this burden, and includes having complete vital (birth and death) registration as an essential component of prevention efforts (Setel et al., 2007). In the South African context, the Department of Home Affairs manages this process more efficiently than other LMICs by including healthcare services at the primary, secondary, and tertiary levels. At all levels of healthcare facilities, from clinics to hospitals, staff from the Department of Home Affairs assist caregivers to complete and file vital registration information of newborns. This system has significantly contributed to the rise in early birth registration (children aged 0 to 31 days), with late birth registrations (children aged 31 days to 14 years) declining (Hall K et al., 2019a). If these births were not registered, these children would miss out on vital services such as the child support grant, healthcare, and access to education. Furthermore, structural factors associated with poverty such as low-income levels, type of employment, distance to a healthcare facility, and waiting time at the healthcare facility also impact the collection of routine data (births and deaths) (Setel et al., 2007).

Monitoring child injury mortality is important because it can help in identifying the distribution and determinants of the injury burden among children, their unmet needs, and to advocate for improved prevention strategies and management of healthcare services to reduce child injury mortality. To further improve the prevention of child injury mortality, spatial analytical tools can be used to improve the monitoring of this burden by highlighting the importance of place, time, and the environment as contributors to the risk of child injury mortality.

1.4 Geotagging Child Injuries

Identifying when and where injuries occur will indicate who is most vulnerable. Geotagging is an important tool in public health research that can be used to determine access to care; population distribution to health, such as the socio-economic conditions of neighbourhoods and population density; spatial allocations of disease burdens such as child RTCs; and proximity to environmental health hazards (Do et al., 2020). Sartorius et al. (2011) found that there were significant geographical differences in infant mortality rate within and across

provinces in South Africa, concluding that this burden was not uniformly distributed but relative to geographical location and dependent on specific factors such as maternal mortality, antenatal HIV prevalence, previous sibling mortality, and male infant gender (B. K. Sartorius et al., 2011). In 2014, the city of Hyderabad, India conducted a case study on RTCs using geographical information systems (GIS), by implementing a mapping component to highlight the nature of RTC incidents and vulnerable RTC hotspots in the city (Bhagyaiah & Shrinagesh, 2014). Transport officials from the city of Hyderabad used the study findings to improve road safety infrastructure with the potential to influence the prevention of RTC deaths in these areas.

1.5 Study Rationale

Globally, the injury COD distribution for children is not uniform and differs by age. Younger children are more likely to die from unintentional causes such as RTC injuries, while adolescents are more likely to die from intentional causes such as interpersonal violence during the teenage years (Institute for Health Metrics and Evaluation, 2021). The leading causes of non-fatal injuries affecting children have remained unchanged over time, with RTCs being the greatest burden. Resources to prevent child deaths are primarily focused on natural causes, such as lower respiratory tract infections (LRTIs), despite the injury burden of children increasing with age. It is therefore important to strengthen the monitoring of child injury burden in South Africa for all age groups over time, so that effective preventative measures can be developed.

This thesis focuses on the child injury burden in the City of Cape Town (CoCT) by identifying the age groups that are most at risk, the most likely cause of death (COD), and the most impacted geographical areas with their associated deprivation level. The childhood injury mortality burden in South Africa has increased significantly over time; however, the government has not prioritised its prevention. Therefore, investigating the pattern of child injury mortality over time, and identifying the leading causes such as the years of life lost (YYL), can help to prevent these deaths. Additionally, by using Global Positioning System (GPS) coordinates, each death can be linked to the suburb where it occurred, creating a heat map across the study area for all age groups. The heat map can identify the suburbs with the highest density of childhood injuries overall and by each age group for the top three leading COD across the study area. This will help in contributing to the development, evaluation, and implementation of more targeted childhood injury interventions in the CoCT.

Transport-related mortality has been identified as a major contributor to the injury burden across South Africa. To determine the risk factors of transport-related mortality; a spatial regression model was developed to investigate the impact of age group, gender, the deprivation level of a suburb, speed limits, and number of lanes. These risk factors go beyond categorising the suburb (rural or urban) and provide greater insight into the role of socioeconomic factors on this burden. Of all transport-related mortalities, RTC contributed the most to the injury burden. Therefore, in addition to determining the pattern of RTC deaths, exploring the morbidity and hospital admission of children due to this cause of injury is vital in developing age-appropriate interventions.

This thesis identified the injury burden of children aged 0 to 17 years old by exploring each manner of death in the context of gender and age across the Metro West, CoCT. Subsequent analysis investigated the spatiotemporal relationship of all transport-related fatalities from 2011 to 2015 across the study area. The mortality and morbidity of road traffic crash injuries were investigated to highlight the significance of this burden in children.

Chapter 2: Literature Review

This chapter will address the literature relevant to the study by first introducing the concept of global epidemiology of child injuries and South Africa's estimates for child injury mortality. The global injury mortality surveillance statistics and how they are recorded will be explored, followed by a discussion on the injury mortality pattern and its geographical differences, including the overall risk factors, and risk factors specific for RTCs. Finally, South Africa's policy environment in the context of child injuries will be discussed.

The pattern of injury mortality in South Africa and the quality of injury mortality data were explored in Chapter 1. Although a systematic literature review was not related to the area under investigation, a systematic approach to conducting the literature review was followed. Literature was sourced using search engines accessed via the University of Cape Town (UCT) library's website and Google Scholar. The search terms included: injury, epidemiology, South Africa, child injury, SatScan, injury mortality; and spatial epidemiology. In addition, from 2019 to 2020, more specific literature was extracted from reference lists of journal articles and the World Health Organization's (WHO) website and publications. All sourced literature was added to an Endnote library (Endnote X9, 2020).

2.1 Global and National Estimates of Child Injury Mortality

2.1.1 Global Estimates of Child Injury Mortality

Global estimates for injuries estimate that in 2017, more than 6,763 people per 100,000 population sustained injuries that required some form of healthcare intervention (James et al., 2020). It is estimated that only 10% of global injuries were experienced by children in 2015 (Wang et al., 2017); however, in 2019, child injury mortality increased (Institute for Health Metrics and Evaluation, 2021). For children, males aged 15 to 19 years accounted for the highest rate of injury-related disability-adjusted life years lost (DALYs) (Haagsma et al., 2016).

Globally, injuries accounted for 13% of child deaths in 2019, which ranged between approximately 25 % and 12 % for low - to high-income countries, (Institute for Health Metrics and Evaluation, 2021). The global age-standardised injury death rates declined, from 84.7 per 100 000 children aged 0 to 14 years in 1990 to 54.6 per 100 000 children aged 0 to 14 years in 2019 (Institute for Health Metrics and Evaluation, 2021).

For children aged 0 to 14 years, RTC has remained the leading cause of injury mortality with a global reported rate of 5.1 per 100,000 in 2019, followed by homicide (3.2 per 100,000), drowning (3.0 per 100,000), and falls (1.25 per 100,000) (Institute for Health Metrics and Evaluation, 2021). Globally, there are 15 RTC deaths per 100,000 population (adults and children) per year, with non-fatal RTCs estimated at 1,052 per 100,000 population (Institute for Health Metrics and Evaluation, 2021). The leading cause of injury death for children in LMIC's is RTCs (Institute for Health Metrics and Evaluation, 2021). The 2019 global estimate for RTC mortality was approximately 7 per 100 000 children aged 0 to 14 years, with the highest rates in Africa (7.3 per 100 000 children aged 0 to 14 years), followed by Asia (4.4 per 100 000 children aged 0 to 14) (Institute for Health Metrics and Evaluation, 2021).'

2.1.2 National Estimates of Child Injury Mortality

SAMRC Burden of Disease (BoD) unit studies have reported national injury estimates for South Africa (Groenewald et al., 2017; Pillay-van Wyk et al., 2016; Prinsloo et al., 2021). The second BoD study reported that in 2012, injuries accounted for 9.6% of all COD in South Africa, with injury-related deaths increasing from 1997 to 2012 (Bradshaw et al., 2010). Most of these deaths affected young adults aged 15 to 29 years old (Pillay-van Wyk et al., 2016). Child injury mortality increases as the child gets older (Table 2.1). Understanding the true magnitude of child injuries is difficult as injury data is mainly presented for the 15 to 19 year age group, which is outside the UN definition of a child as. However, the disaggregation of child injury data in this manner across BoD studies has implications for understanding the true magnitude of injuries during childhood and the pattern of injuries, which is necessary for targeting childhood injury risk.

Table 2.1

Injury mortality rate for children aged 0-14 years globally, in South Africa, and the Western Cape by leading causes of death

COD	Global (Cases per 100,000 population)		South Africa (Cases per 100,000 population)		Western Cape (Cases per 100,000 population)	
	0-4 years	5-14 years	0-4 years	5-14 years	0-4 years	5-14 years
RTC	7.2	4.8	13.5	11.2	12.8*	4.3*

Homicide	1.7	0.8	5.2	3.1	20.0	24.0**
Suicide	0.0	0.6	0.0	1.4	0.0	8.0***

*Western Cape Injury Mortality Profile 2010-2016 report: Number of deaths 2016: pedestrian (12.8 per 100,000 population); pedestrian (4.3 per 100,000 population-average over 5-9 years and 10-14 years)

**Western Cape Injury Mortality Profile 2010-2016 report: Average deaths over 2010-2016: 5-9 years (6 per 100,000 population); 10-14 years (18 per 100,000 population)

***Western Cape Injury Mortality Profile 2010-2016 report: Average deaths over 2010-2016: 5-9 years (1 per 100,000 population); 10-14 years (8 per 100,000 population)

Injury Mortality Survey 2009 data

£IHME 2021 data

The Injury Mortality Survey (IMS) generated national estimates for injury-related deaths by age group to explore vulnerability by type of injury across childhood (Groenewald P, 2020). The IMS combined data sources that included forensic pathology data for classifying COD by case, to provide an accurate COD compared to the death notification data. However, this approach has limitations due to the large number of cases in which the COD is coded as ill-defined, with a number of critiques having noted that the sub-optimal quality of COD certification by medical practitioners is a major factor contributing to this problem (Groenewald P, 2020). To improve death data, additional data sources were utilised to verify COD, i.e., data from police reports can provide insights into the manner of death, determining if the death was an accident or was with intent. To date, there have been two IMS studies published, one utilising nationwide mortuary data from 2009 and the other from 2017. The latest IMS study found that RTC injuries were the leading mechanism of injury death followed by homicide for children aged 0 to 14 years (Prinsloo et al., 2021). According to this thesis, homicide and RTC injury have a bimodal pattern, mainly affecting children older than 15 years, followed by those younger than 5 years (Prinsloo et al., 2021). Of all the forms of injury deaths, a marked difference was observed in the homicide rate of South African children compared to global estimates, especially in children older than 15 years. The homicide rate for South African children in 2009 was 17.4 per 100,000 children aged 15 to 17 years (Mathews et al., 2019). This is nearly three times higher than the global estimates in 2010 (Institute for Health Metrics and Evaluation, 2021).

In 2017, homicide was the most common cause of injury mortality in the Western Cape across all age groups (Prinsloo et al., 2021), and the second leading cause of years of life lost (YLL) according to the BoD study e (Pillay-van Wyk et al., 2016). Evans (2018) also reported that child injuries contributed to 13% of all-fatalities in the Western Cape, with most deaths occurring in male adolescents aged 15 to 19 years old. It was also found that in the Western Cape, this age group was more vulnerable to a violent deaths from homicide than any other injury causes.

National injury mortality estimates for children published by the BoD unit of the South African Medical Research Council (SAMRC) range from 0 to 19 years, with different patterns of injury observed across age groups. These estimates have identified the difference in injury trend by age grouping where younger children (9 years and younger) are more likely to be involved in an RTC compared to older children who are more likely to succumb to injuries because of a homicide. However, the injury burden gets hidden among adolescents (individuals aged 10 to 19 years) and young adults (individuals aged 18 years and older), especially for homicides. This PhD study takes an explicit child-centred approach by focusing on children 17 years and younger in the analysis,, the universally accepted definition of a child as defined by the United Nations.

Due to the rising RTC burden among children in South Africa, this PhD study aimed to estimate the overall child injury burden for the CoCT from 2011 to 2015, with a specific focus on RTCs. This analysis extended beyond the RTC mortality trend, to understand the level of disability experienced by a child following an RTC incident. Additionally, this PhD study gained a deeper understanding of the risk factors influencing the child injury burden by conducting a spatial analysis of factors such as the level of deprivation of the geographic location. Previous studies have considered the characteristics of an area and predominantly focused on rural or urban location of an incident. However, this PhD study extended the analysis to consider how the characteristics of the geographic location affected injury risk among children. This characterisation is important in guiding policy and implementing preventative initiatives; however, knowing the level of deprivation provides insight better understanding of the socioeconomic status of the area at risk, which contributes to the likelihood of an injury, especially in children. All these factors help guide injury prevention initiatives.

2.2 Conceptual Framework

The conceptual framework used in this thesis focused on spatial epidemiology encompassing concepts of human geography. The next section describes how concepts of spatial epidemiology will assisted in shaping the framework for this thesis.

Walter Tobler’s First Law of Geography: “Everything is related to everything else, but near things are more related than distant things” (Tobler, 1970).

The conceptual framework from Augustin et al. (2023), provided an overarching framework for this thesis. This is one of the first conceptual frameworks that integrates the determinants of health and spatial aspects of health (Augustin et al., 2023). The social determinants of health, such as where people are and its impact on the health status of an individual, are well described. However, there are limited models of health that highlight the interaction between place and health. The spatial aspects of health are known to be interdisciplinary, encompassing the health needs of individuals, socioeconomic factors (like deprivation level), and demographic factors (like gender and age) (Augustin et al., 2023). Health and place interact at various geographical levels: global, national, community, and suburb. Each geographical level depends on where a person lives, the socioeconomic and demographic composition of the area, and the health needs of individuals (Augustin et al., 2023) See Figure 2.1 adapted from Augustin et al., 2023.

Figure 2.1

Spatial determinants of health conceptual framework adapted from Augustin et al., 2023

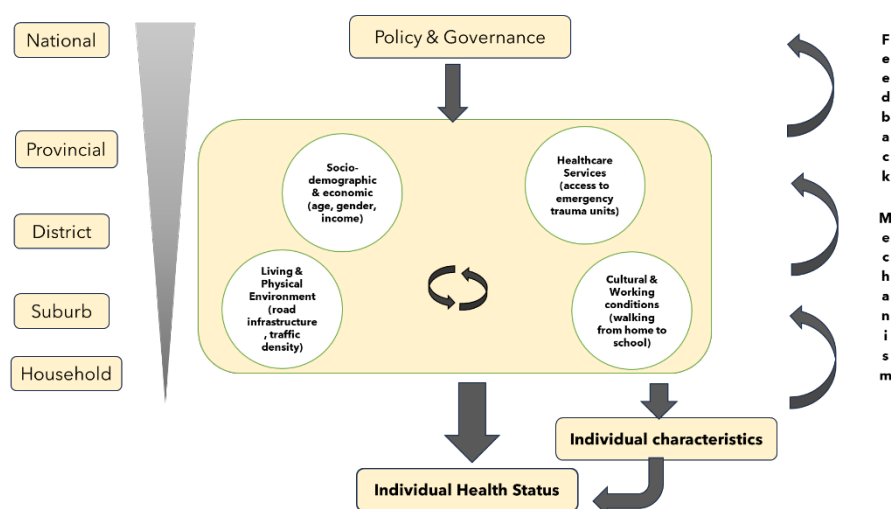


Figure 2.1 illustrates the spatial determinants of the health conceptual framework which show how individual health status is affected by their socio-demographic and economic (age, gender, income); living and physical environment (road infrastructure, traffic density); healthcare services (access to emergency trauma units); and cultural and working conditions (walking from home to school) (Augustin et al., 2023). These determinants are interrelated and are affected by global factors (urban design) and policy, both at national and provincial level in South Africa. This PhD study focused on the suburb level, which is equivalent to a neighborhood, in this conceptual framework.

Social determinants of health are key components of this conceptual framework, with health inequality a key outcome (Augustin et al., 2023). Children in deprived communities have limited access to safe spaces to play, both at home and in their communities. They are often forced to use communal spaces, which can be dangerous and overcrowded. More affluent communities on the other hand have many safe spaces for children to play, like parks and recreational spaces with large fences. This highlights the underlying inequality in spaces within communities. To prevent child injuries and strengthen initiatives, an understanding of the spatial organisation of the socioeconomic environments is needed (Bell & Schuurman, 2010). Each geographical level comes with its own socioeconomic challenges; for example, in Canada child pedestrian injury prevalence decreased incrementally for every 160 m from collision sites and residential homes (Lightstone et al., 2001). This would suggest that children who play in a safe space near their homes, such as a fenced-in play area, are less likely to be involved in an RTC than children who play in areas that are not designed with children's safety in mind.

The use of this conceptual framework emphasises the importance of incorporating spatial scales and health determinants when assessing child injury risk and developing injury morbidity and mortality prevention strategies among children.

2.3 Spatial Epidemiology

Spatial epidemiology bridges the gap between geography and epidemiology. It encompasses four areas of study namely disease mapping, spatial exposure assessment, disease risk assessment, and cluster detection (Kanaroglou & Delmelle, 2016). Mapping where an incident occurs allows one to visualise the spatial patterns of injuries, i.e., transport-related fatality, by

determining the variability in risk to socioeconomic factors such as deprivation score assigned to suburbs. This is a fundamental principle of spatial modelling for determining risk through exposure.

Cluster detection is an important component of surveillance and is concerned with determining spatial patterns of disease, varying from the unexpected to the expected. Depending on the research question, there are many ways to determine clusters within data. This includes auto-correlations and K-functions that focus on proximity, kernel functions used to estimate the intensity or density of the disease outcome, and a moving window approach (i.e., scan statistic). This thesis incorporates a scan statistic using Satscan to determine the likelihood of transport-related clusters across the study area over time. The spatial properties of data can link numerical and graphical procedures with a map. An early example of spatial epidemiology is Dr John Snow's investigation of deaths from cholera in London in September 1854, in which the spatial clustering of cholera deaths was found to be located around an infected water pump that was linked to the river Thames (GIS analysis of Snow's London cholera map, 2015).

Several studies have shown the importance of visualising the pattern of cause-specific mortality of children to determine which areas are at high risk and require the strengthening of services through effective resource allocation (de Oliveira & de Freitas Mathias, 2013; B. Sartorius et al., 2011; Sartorius et al., 2010). In 2011, Sartorius et al. (2011) found that there were significant geographical differences in the infant mortality rate within and across provinces in South Africa. They concluded that this burden was not uniformly distributed but was related to geographical location and dependent on specific factors such as previous sibling mortality (Sartorius et al., 2011). Additionally, de Oliveira and de Freitas Mathias (2013) found that by utilising Local Morans I, a weighted correlation coefficient used to detect dependence from spatial randomness, it was possible to determine the likelihood of infant mortality clusters across three health districts in Parana region, Brazil, with most infant deaths being preventable.

GIS tools can also be used in the surveillance of injury-related deaths. Spatial and temporal mapping can highlight hotspots and cold spots of all forms of injury-related deaths such as homicide (Messner et al., 1999), suicide (Chang et al., 2012), drowning (Dai et al., 2013), burns (Bell et al., 2012), and RTCs (Razzak et al., 2011).

There is little known about where children are injured or killed in an RTC incident. The utility of this methodology is evident in a study by Bhagyaiah and Shrinagesh (2014) in the city of Hyderabad, India, where a case study of RTCs using GIS to implement a mapping component highlighting the nature of RTC incidents and vulnerable RTC hotspots in the city was conducted. The information gathered by the authors indicates that the transport sector of Hyderabad could improve its services in these areas, including the appropriate road safety infrastructure needed to prevent RTC deaths at these hotspots. This thesis will utilise a similar methodology by highlighting transport-related fatality hotspots and their risk factors in specific areas based on how deprived the neighbourhood is.

Using GIS cluster analysis, a study conducted in Pakistan identified areas at high risk for RTC incidence relative to the number of injuries within the area (Razzak et al., 2011). In Brazil, researchers found a higher incidence of RTCs on highways and showed an correlation with the built environment variables such as the length of road in an urban area, limited lighting of roads, double lane roadways, and fewer auxiliary lanes (de Andrade et al., 2014). These studies have underscored the practical utility of employing GIS tools for identifying areas at risk of RTC burden on a national scale, emphasising the importance of collecting accurate, relevant, and timely data necessary for effective burden monitoring. Therefore, such studies have the potential to enhance policies and initiatives aimed at prioritising safety in the areas where children live, play, and walk to school, a crucial step in mitigating RTCs in most at-risk communities. In addition, this approach can also assist in resource allocation. A study In Kenya, using a health service provider database displayed the areas of inequitable access to healthcare across the country and assisted the Kenyan Ministry of Health in allocating resources to areas in need (Noor et al., 2004). Furthermore, this data can identify areas where interventions have been successful and evaluate the performance of the healthcare system (de Oliveira & de Freitas Mathias, 2013).

2.4 Social Determinants of Health

Social determinants of health (SDH) are various social, economic, and environmental factors that influence the health of individuals and communities (Braveman et al., 2011; Currie et al., 2009; Halfon et al., 2010; WHO, 2010). Individual health is influenced by various factors including economic status, education, social support networks (provided by families and

communities), gender, time availability, access to and utilization of healthcare services, in addition to the quality of physical environments encompassing clean water, unpolluted air, secure housing, resilient communities, and safe roadways. SDH results in health inequities in the society and is driven by social, economic, and environmental factors that influence the unfair and avoidable differences in the quality of an individual's health and healthcare services (World Health Organization, 2010).

The Diderichsens' model of the mechanisms of health inequality shows how people's social position can affect their health in a society (World Health Organization, 2010). The model identifies the ways that social factors can lead to different health outcomes and includes the social structure and how it stratifies people into different groups, which can lead to differential exposure to health-damaging conditions, differential vulnerability to health conditions, and differential consequences of poor health in both affluent and non-affluent groups (World Health Organization, 2010). The health status of an individual is influenced by their social class, living conditions, access to healthcare, and type of employment. Premature death from various diseases, especially among vulnerable groups such as children, is significantly influenced by SDH. Important factors that influence health outcomes include rising inequities within and between countries; new patterns of consumption of goods such as food; global environmental change; and urbanisation such as transportation, social protection, and job creation (World Health Organization, 2006).

Children are often overlooked when discussing inequalities related to socioeconomic status, age, and gender (Currie et al., 2009). Children living in low-income households are less likely to have sufficient access to health services (Gabhainn et al., 2009), with household wealth distribution significantly contributing to the overall health of children. Emerson et al. (2005) also state that compared to children living in high-income households, those living in a low-income household are more likely to have poor overall health and suffer from emotional disorders such as depression. The study found that boys aged 5 to 10 years and living in a low-income household were 1.8 times more likely to be involved in accidental injuries such as fractures and burns compared to those living in a high-income household (Emerson et al., 2005).

Time is a critical factor in the occurrence of different types of injuries. For example, RTCs are more likely to happen at night especially in areas with poor lighting, or during rush hour on weekdays when traffic density is high and visibility poor. A health centre in Alexandra township in Johannesburg, South Africa, reported that 56% of transport injuries and 38% of other unintentional injuries happened between Friday and Sunday (Zwi et al., 1995). In the Western Cape, most injury deaths (both intentional and unintentional) occurred over the weekend. Homicide, RTC, and fire-related deaths peaked between 12 am and 3.59 am on Sunday mornings, compared to drowning deaths, which peaked between 1 p.m. and 4.59 p.m. on Sunday afternoon (Evans, 2018). Similarly, Red Cross Children's hospital reported that over a 10-year period, majority of the RTC injuries occurred over the weekend compared to weekdays (Burstein et al., 2016). Death causing injuries in South African children varies with age. Homicide is the leading cause of death for children aged 15 years and older, while RTCs are the leading cause of death for children of all ages (Matzopoulos et al., 2015). However, the socio-economic status (SES) of children further exacerbates their injury risk.

2.4.1 Socio-economic Determinants

The global injury burden is greatest among children from low-income households (Peden, 2008). The social determinants of the health of a community can greatly impact the injury burden experienced by vulnerable individuals. For example, in cities with poor socioeconomic conditions, such as high unemployment, income inequality, and overcrowding, the incidence of injury-related deaths increases (Collings, 2004; Gururaj, 2004; Lipsey & Derzon, 1998).

The CoCT is densely populated with 28.4% of the population younger than 18 years old. 26% of individuals in the city are unemployed, and 1 in 5 children live in overcrowded conditions, with a higher rate in township and shack dwellers. The characteristics of the CoCT are discussed in more detail in Chapter 3, page 32. Those living in backyards and shacks lack basic amenities like electricity and running water, and the need to use paraffin and fire to cook and keep warm increases the risk of injuries for children living in these conditions. In the CoCT, it was found that burn injuries were most prevalent among impoverished and derived population groups (Van Niekerk et al., 2009), with children most at risk.

*Child is defined by the United Nations Convention of the Rights of a Child as “a human being below the age of 18 years unless under the law applicable to the child, majority is attained earlier.”

In Brazil, a study revealed higher homicide rates in poor neighbourhoods, with residents having a low SES (Santos et al., 2006). The poorest neighbourhoods had the highest proportion of informal households (96.2%) and the lowest educational levels (Santos et al., 2006). Similarly, two of the most deprived neighbourhoods in the CoCT, Khayelitsha and Nyanga, have one of the highest homicide rates in South Africa and are mainly comprised of informal households (i.e., shacks), with most individuals living below the poverty line (Pinnock, 2016a). These areas are characterised by not only poor socio-economic conditions, such as a lack of basic services, but also social issues, including organized crime, drug use, crime, and homicide.(Pinnock, 2016a).

Gangs in the CoCT, are part of the informal economy, which is partly due to high youth unemployment rates and a lack of employment opportunities in their communities. These conditions attract adolescents and young men to gangs (Pinnock, 2016a). High levels of gang activity have had a significant impact on communities, making residents feel unsafe and changing the way they live.. In poor communities, children often idolise and respect gang members because they represent power and control (Pinnock, 2016a). Gangs are hierarchical organisations with strict rules and codes of conduct and often promote a hyper-masculine culture that is attractive to young men. The surge in gang membership is a result of the increase in unemployment rates, school dropout rates, poverty, and crime in the community (Pinnock, 2016b). Gang recruitment is a complex process comprising crime, violence, and the fact that gangs form part of these young men's social environment (Pinnock, 2016a).

2.5 Injury Mortality and Geolocation

2.5.1 Injury Risk Factors

Injuries are associated with several environmental and social risk factors. The literature highlighted that males (Celis, 1997), large family size (Rahman, 2005), low maternal education (Tiikkaja et al., 2009), a child's main caregiver not being the mother (Rahman, 2005), poor households classified as having a low wealth index (Morrow et al., 2013), and single-parent households (Howe et al., 2006) increase the incidence of injury deaths. However, injury risk factors are also categorised depending on the age of the child and whether the death was intentional or unintentional. Although suicide and homicide have their own risks, most of the child injury epidemiology literature is focused on risk factors associated with unintentional injuries, especially in children younger than 5 years. Injury from burns is more prevalent in

this age group. The Young Lives study revealed that children (averaging 12 months old) in Ethiopia, Peru, Vietnam, and Andhra Pradesh, India, face a higher risk of fire-related burns if they live in informal rural households. This risk is greater than that faced by children in urban homes with formal structures, where open flames are not used for cooking and heating. (Howe et al., 2006). However, intentional injuries such as homicide are more prevalent in older children, with the leading risk factor being drugs and involvement in gang activities (Törő et al., 2010).

2.5.2 Risk Factors for Road Traffic Crashes

Several risk factors increase a child's susceptibility to being involved in an RTC, which is consolidated in the Haddon Matrix, a conceptual framework used as a tool to systematically assess RTC risk. Most of the risk factors that increase the likelihood of an RTC for the general population also impact children. This includes speeding, driving while under the influence of alcohol or drugs, using unsafe vehicle equipment, and inadequate road infrastructure.

Table 2.2

Haddon Matrix -- RTC risk factors -- (Peden et al., 2004)

	Pre-event	Event	Post-event
Child Factors	Age; gender; lack of supervision; impulsive behaviour; disobedience; lack of police enforcement	Size and physical development of the child; lack of equipment of to protect occupants; or equipment improperly used; underlying conditions in child	Childs lack of resilience; child's general condition; lack of access to appropriate healthcare; post-injury complications.
Vehicle and Safety equipment	Lack of roadworthiness of vehicle; poor lighting; poor state of breaks; speeding; overloading.	Child restraints and seat-belts not fitted or incorrectly used; bicycle and motorcycle helmets not used; poor design of vehicle for protection in crashes; no rollover protection.	Difficult to access victim; lack of trained healthcare and rescue workers.
Physical environment	Poor road design; lack of public transport; no enforcement of speed limits; no safety barriers; lack of alcohol laws; poor infrastructure for pedestrian laws.	Road side objects such as trees and poles.	Lack of availability of adequate pre-hospital care; acute care and rehabilitation.
Socio-economic environment	Poverty single-parent family; large family size; poor maternal education; lack of awareness of risks among caregivers; childcare providers and educators.	Lack of safety culture in the care and on the road.	Lack of culture of supporting injured people; no first aid given at scene.

However, certain risk factors uniquely affect children. The road infrastructure, for instance, doesn't consider vulnerable groups like children, who face a heightened risk of pedestrian road traffic collisions due to various factors. Risk factors for RTCs are discussed in the following section, utilising the Haddon Matrix framework (Table 2.2).

The RTC risk factors for children are childhood factors, vehicle and safety equipment, physical environment, and socio-economic environment. The Haddon Matrix utilises a systems-based

approach to highlight possible injury-preventative measures that aim to correct errors in design and reduce the severity and likelihood of an injury from occurring through:

- Limiting exposure to risk factors;
- Reducing the likelihood of RTCs;
- Lessening injury severity during an RTC; and
- Improving post-crash care to lessen the factors contributing to RTC incidence.

Practical implementation of this approach includes reducing speed limits in urban areas, building raised pavements/sidewalks, modifying car and bus designs that protect pedestrians, and crash-protective barriers between road infrastructure and vehicles. Since implementing this integrated approach, several countries have observed a significant decline in RTC morbidity and mortality. The most impactful risk factors to consider for an RTC incident involving children are: pre-event, child factors and gender.

2.5.2.1 Gender

A gendered difference was reported in SSA where in 2014, the RTC mortality rate for male children was greater than the rate for female children (Institute for Health Metrics and Evaluation, 2021). In 2017, In South Africa, male children younger than 14 years were found to be 1.3 times more likely than female children to be involved in a fatal RTC incident (Prinsloo et al., 2021). Similarly, according to Isaac et al. (2015), male children younger than 13 years were 1.7 times more likely than female children ($p < .05$) to be admitted to the Red Cross War Memorial Children's Hospital (RCCH) trauma unit for a non-fatal RTC injury in 1999, 2002, and 2012.

Risk-taking behaviour and parenting style both influence the likelihood of males being more involved in an RTC incident than females. A study in the UK found males inherently take more risks than females as they tend to be more adventurous while exploring their surroundings during playing (Harré, 2000; Waylen & McKenna, 2008). This risk-taking behaviour can also be attributed to parents closely monitoring female children compared to males children and from distinct gender-based socialisation that prompts males to take greater risks (Harré, 2000; Waylen & McKenna, 2008).

2.5.2.2 Age

The South African national estimate of RTC mortality in 2017 for children younger than 14 years was nearly twice as high as the globally reported estimate (Prinsloo et al., 2021). This high RTC mortality rate for children can be attributed to amongst other things, a lack of traffic calming interventions.

As children grow older, they become more independent and require less supervision. Children 10 years and older start taking more risks crossing the road without checking for traffic (Harré, 2000; Waylen & McKenna, 2008).

2.5.2.3 Supervision

Age and gender are not the only factors that influence risk taking behaviour and overall RTC incidence. Supervision is thought to be a major driver of risk for any injury incident, particularly RTCs. Caregiver supervision, particularly in young children, is essential to prevent an RTC injury. The circumstances surrounding RTC deaths suggest that unsupervised or unattended children along the roadside increases their RTC risk, especially those younger than 5 years old (CDR, personal communication). Furthermore, children in South Africa, living in informal settlements in urban areas, are particularly vulnerable due to various factors; for example, caregivers who have jobs often have to use public transportation, which means they have to wake up early and return home late due to poor public transportation services coupled with the long distances travelled from far-flung townships. This and a combination of a lack of supervision and a small home can lead to children playing in unsafe spaces. Parenting practices and societal norms can leave children unsupervised, putting them at risk and vulnerable to dangers such as being involved in an RTC as a pedestrian.

A study conducted in two residential areas in Cape Town to determine child pedestrian safety knowledge in children aged 6 to 15 years found that more than 80% of children walked to school (Koekemoer et al., 2017). These children were mostly unsupervised and lived within a 10-minute walking distance from their school, with 35.1% having experienced pedestrian collisions (Koekemoer et al., 2017). Both areas are in low-income communities with elevated traffic injury rates and heavy traffic volume along routes to schools. Interestingly, it was found that children who spent more time walking were more likely to engage in risky behaviour, but they were also better at navigating road traffic than young children and those children who

spent less time walking (Koekemoer et al., 2017). Therefore, if children can walk to school safely, i.e., supervised by volunteer carers, they will more likely be able to safely navigate their journey back home, potentially reducing the RTCs incidence.

2.5.2.4 Vehicle and Equipment Safety

One of the greatest RTC risks for child pedestrians is speeding motor vehicles. The speed of a motor vehicle is a major factor in the likelihood of an RTC incident. Vehicles travelling at speeds greater than 80 km/h increase the risk of death of a pedestrian by 60 % for adults and at an even greater risk for children because of their physical size (World Health Organization, 2015a). The lack of speeding law enforcement in countries is a major contributing factor to the high incidence of RTC injury mortality and morbidity. According to the latest Global Road Safety report, countries with high RTC incidence rates had insufficient enforcement of speeding laws such as a national speed limit law; maximum speed in urban areas and rural areas, and maximum speed on highways (World Health Organization, 2018). All these factors continue to increase RTC incidents, especially for vulnerable populations such as children (World Health Organization, 2018). Studies have shown that countries that prioritise traffic engineering countermeasures, such as speed-reducing measures, pedestrians barriers, and pedestrian visibility enhancements, have lower RTC burdens (Retting et al., 2003). In 2015, Thailand amended the national speed legislation to reduce speed limits in residential areas and near schools to align with the best practice of 50 km/h but was unsuccessful. However, by 2018, nearly half of the provinces in Thailand had set appropriate speed limits of no more than 50 km/h on urban roads because local governments were empowered and encouraged to set their own speed limits; thus creating a positive influence in their localities to reduce the RTC incidence across provinces (World Health Organization, 2018).

Additionally, in the Netherlands, Schoon when 180 intersections with stop signs were replaced with roundabouts, pedestrian-vehicle crashes were reduced by 73% because vehicles needed to slow down to 20 km/h before entering the roundabout (Schoon & van Minnen, 1994). In 2009, the design of roads in Canada encouraged high-speed travel, and the likelihood of a fatal RTC incident was 8.9 times higher on roads divided by a barrier separating vehicles traveling in opposite directions.(Rifaat et al., 2011).

2.5.2.5 Physical Environment

The physical environment, such as road design, home building materials, and a safety fence surrounding a swimming pool, influences the risk of injuries in children. The RTC burden is affected by the physical environment of an area, especially for pedestrians. The physical environment of areas with high RTC incidence is characterised by a lack of raised sidewalks and playgrounds, forcing pedestrians to share the road with motor vehicles, cyclists, and motorcyclists. Furthermore, narrow, unpaved, and unlit roads can contribute to high RTC injury rates, especially when vehicles are speeding (Derry et al., 2007; Mock et al., 1999).

Traffic density, a characteristic of traffic flow, is another RTC risk factor (Al-Sobky & Mousa, 2016). A study in Ghana found that more than half of RTCs occurred on rural roads (52.3%) compared to urban roads (47.7%) (Afukaar et al., 2003). However, in Uganda, it was found that transport injuries were higher in urban areas, where the traffic density was higher compared to rural areas with low traffic density (Kobusingye & Lett, 2000). The link between RTC incidents and traffic density is also influenced by the mode of transport, such as private vehicles, buses, and taxis.

In South Africa, despite having the highest traffic density compared to other provinces, Gauteng Province and Western Cape Province reported the lowest passenger fatalities. However, Kwa-Zulu Natal, with 21.5% of children in South Africa, and with more rural than urban communities, had the highest passenger fatality rate (Road Traffic Management Corporation, 2020).

2.5.2.6 Inequity

Inequity is a risk factor for RTC burden in all countries irrespective of income level (Peden, 2008). Several factors explain the inverse relationship between SES and child injuries. Communities with high traffic density; limited speed limit laws, including lack of enforcement of these laws; and a lack of cost-effective road safety interventions such as speed bumps (Mueller et al., 1990), are characterised as having a low SES, which leads to a high RTC incidence rate (Mueller et al., 1990). In low SES neighbourhoods, the lack of barriers between homes and the street makes it difficult to create safe spaces for children to play away from the traffic. This proximity to traffic dense roads increases the risk of child pedestrian injury and

mortality (Sharples et al., 1990). Canadian children from low-income households were found to be more likely to experience accidental injury (Currie & Stabile, 2003), while in the UK, children from poorer areas were five times more likely to die from an injury compared to those residing in wealthier areas (P Townsend, 1982).

2.5.2.7 Event

The severity of an injury sustained during an RTC incident is dependent on the size and physical development of a child. The prevalence of pedestrian injury in children can be partly attributed to their small physical stature, which can make them difficult for the drivers to see. In an RTC passenger incident, factors such as the use of child restraints, such as car seats, and the speed of the vehicle, influence RTC severity and the likelihood of death. The speed of the vehicle also increases the risk for RTC pedestrians. The higher the speed of a vehicle, the less likely the driver will be able to slow down to prevent a collision with another car, physical structure, or pedestrian.

Passengers in a moving vehicle, should wear a seatbelt to prevent severe injury or death in the event of an accident (Delavary Foroutaghe et al., 2020; Slyunkina et al., 2013; World Health Organization, 2015b). To prevent passenger injuries in young children, a car seat must be installed correctly and used appropriately to keep the child safe while travelling in the vehicle. In countries where child restraint laws were implemented and enforced, the RTC morbidity rate for children declined by 82% (Zaloshnja et al., 2007) and the RTC mortality by 28% (Elliott et al., 2006). Child restraint laws are more common in HICs than LMICs.

South Africa enacted its child restraint law in 2014. However, the proportion of passenger fatalities for children younger than-5 years remained unchanged at 5% between 2015 and 2019, with the lowest proportion of fatalities occurring in 2017 at 3.8% (Road Traffic Management Corporation, 2015, 2017, 2020). Child restraint use remains low in South Africa, especially in vehicles where the driver does not wear a seatbelt (Hallbauer et al., 2011). Furthermore, the limited use of child restraints is associated with ambiguity in the Road Traffic Act, such as the type of restraint to be used, the safest position for the restraint, the age at which children are required to use restraints, and inadequate penalties for non-compliance, impacting driver adherence to the law (Janmohammed et al., 2019).

2.5.2.8 Post Event - Post-crash Care

After an RTC incident has occurred, several factors such as adequate post-crash care and access to appropriate healthcare influence long-term outcomes. Post-crash care is essential to reduce severe complications or death following an RTC. It includes emergency medical services (EMS) pre-hospital care, and immediate transportation to the nearest tertiary trauma unit following an RTC (Soro & Wayoro, 2017). The level of available post-crash care varies depending on the setting in which the RTC occurred (urban, peri-urban or rural), and if treatment was secured during the “Golden Hour”. The “Golden Hour” is the one-hour timeframe immediately an RTC during which prompt medical attention can significantly improve the chances of survival (Colorado Department of Transport, 2018).

Compared to urban areas, the RTC mortality rate is higher in rural areas because of delayed emergency services, prolonged emergency response time, and greater distance between the RTC scene and an emergency trauma unit (Byrne et al., 2019; Gonzalez et al., 2006; Li et al., 2008). Children in an RTC who were treated at an emergency trauma unit within the "Golden Hour" were at lower risk of severe injury complications or death. Post-crash care in South Africa involves treating all RTC victims within the “Golden Hour”. However, several factors, such as inadequate EMS facilities along the road network within 60 minutes of the incident location (Vanderschuren & McKune, 2015 D, 2015), especially in known high-risk areas, and the delay in admitting patients to the trauma unit (Zuidgeest et al., 2013), can impact the patient’s recovery. This underscores the importance of prompt care post RTC events to reduce injury complications and recovery time.

2.6 South Africa’s Policy Environment

An enabling policy framework is essential to reduce the likelihood of children being involved in injuries with life-long consequences. It is therefore crucial for children’s rights to be translated into policies that are actionable and implemented. Health provisions for children are linked to the “right to the best possible health and access to healthcare”, which encompasses the government's responsibility to guarantee that every child is not deprived of their right to access healthcare services. To prevent child injury deaths, the Convention on the Rights of the Child (CRC) (article 24(2)) states that governments should create opportunities that will diminish infant and child mortality, create safe spaces for children to play, support parents in their ability to parent in a positive manner, provide public health education for parents and

children, and develop preventative healthcare through guidance for parents and family planning education (Unicef, 1989). These rights are linked to the Sustainable Developmental Goals (SDGs) for child injury death prevention, which include health and the child's environment.

2.6.1 *Child Rights and Policy Environment*

Realising children's rights aligns with protecting them from all forms of injury to prevent disability or death (Unicef, 1989). Children have the same human rights as adults, but they also need additional special care and protection. In 1989, the United Nations Convention on the Rights of the Child (UNCRC) became the first legally binding international treaty that included all human rights from civil, cultural, economic, political, and social rights. South Africa has signed the UNCRC agreement and commits to achieve the rights set out by the convention, and must routinely report to the committee on the rights of children as well as the government's progress towards achieving these rights. The UNCRC clearly specifies that every child has a right to a basic quality of life, and is not limited to a privileged few. Children also have the right to develop to their full potential, and to be free from hunger, want, neglect, and abuse. Addressing the needs of children is the first step to realising the rights of children.

South Africa has ratified the UNCRC, and the African Charter on the Rights and Welfare of the Child, with all children's rights protected by the South African Constitution and the Children's Act, 2005 (*Children's Act 38 of 2005*). Section 28 of the constitution guarantees children a direct and unqualified "right to basic nutrition, shelter, basic healthcare services and social services". Therefore, the state must establish definitive measures to uphold children's right to health. This includes adopting effective and appropriate laws, policies, and programmes; ensuring that a basic budget and resources are available; safeguarding the design and delivery of healthcare and other essential services so that they are child-centred; and committed to continuous progress to improve child health outcomes.

Following democracy, South Africa re-conceptualised and re-wrote nearly all its laws and policies to align with the constitution and ratified international agreements and treaties to ensure child health was realised across South Africa.

Specific pieces of legislation (such as driving or child labour) are bound by legal age and can influence children's exposure to injury risk (Peden, 2008).

2.6.2 Rights that Protect Children from Injuries

There are several South African rights and laws that promote the prevention of child injuries and care post-injury. These include:

- Right of every child to basic healthcare services.
- The National Health Act of 2003 is associated with the policy stating that everyone is entitled to free primary healthcare. Therefore, if a child is injured and is taken to a public health facility to receive treatment in a timely manner, the likelihood of dying from an injury is reduced.
- Right of everyone to have access to information that is required for the exercise or protection of any of their rights.
- The National Health Act of 2003 is associated with the policy stating that individuals have the right to have access to information about their health status, treatment options, and risks.
- The Children's Act of 2005 states that each child has the right to access information with regards to health promotion and the prevention, and treatment of ill-health and disease, sexuality, and reproduction. Such awareness campaigns include those that educate children at schools about road safety.
- Right of everyone to have access to adequate housing and the right of every child to shelter.
- The right of everyone to be free from all forms of violence is enshrined in the Constitution of the Republic of South Africa (Act 108 of 1996), which specifies in section 12 that all individuals have the right to freedom and security, including the right to be free from all forms of violence.. Section 28 (1)(d) allows for additional protection for children by ensuring that every child has the right to be protected against maltreatment, neglect, abuse, or degradation.

2.6.3 Sustainable Development Goals (SDGs) and their link to child rights

South Africa has adopted the SDGs, with the government required to report the progress towards these goals. The SDGs aim to embrace economic development, environmental sustainability, and social inclusion, to improve human wellbeing between and within society (Sachs, 2012). All of these are dependent on good governance across all levels, i.e., local, national, regional, and global. Economic development builds on the Millennium

Developmental Goals (United Nations) linked to poverty, hunger, and disease; therefore ensuring that everyone's basic material needs and human rights are met. The main drivers of human-induced global environmental changes need to be addressed to achieve environmental sustainability. These include energy use, food production, urbanisation (including pollution and potential hazards), and increase in population size (Sachs, 2012). Social inclusion encompasses technological progress that is fair and provides equitable access to services; this involves governments negating social discrimination with respect to gender, ethnicity, religion, and race (Sachs, 2012). In 2015, all United Nations member states adopted 17 global goals, named the SDGs, to prevent poverty, protect the planet against climate change, and create opportunities for individuals to live peaceful lives that are free from violence.

To expand injury prevention initiatives in accordance with the SDGs; there are presently two road safety targets within the SDG agenda; these are SDG 3.6 and SDG 11.2. These targets are comprised of 12 voluntary global performance targets and 36 corresponding indicators that are based on a safe system approach. These targets focus on road safety management, safer roads and mobility, safe vehicles, safe road users, and post-crash response. Even though the current SDG agenda has limited attention on injury prevention, it can be advanced within a broad range of SDG goals (Ma et al., 2021).

The SDGs can direct country policy and prioritise interventions and funding for countries to meet these goals; therefore, each country adapts the SDGs relative to the population's requirements. Categorising the SDGs even further into targets enables countries to locally adapt these goals, such as having targets to ensure children's safety. These targets include halving the number of RTC injuries by 2020 (3.6), and reducing all forms of violence and related deaths (16.1) (United Nations, 2019). Both targets are linked to evidence that children are vulnerable to RTC injury and to homicide. The success of the SDGs is measured by their ability to meet their targets and progress towards attaining specific targets and indicators. These targets are measured with surveillance tools that effectively monitor a country's disease burden, by collecting accurate and timely data (Prinsloo et al., 2017). This data should inform the set of targets required to measure the country's progress towards achieving the SDGs (Prinsloo et al., 2017).

This thesis explores the injury burden experienced by children aged 0 to 17 years old by examining each apparent manner of death in the context of gender and age. Further analysis investigates the spatiotemporal relationship of all transport-related fatalities across the period of interest and study area. Road traffic crash injury is identified as one of the leading COD and this thesis investigates both the mortality and morbidity implications of this burden in children.

Chapter 3: Context, Aims and Outline

3.1 Study Rationale

Globally, adults and children share a similar COD pattern, with communicable and injury causes being the greatest burden (Institute for Health Metrics and Evaluation, 2021). The COD injury pattern in children differs by age. While younger children are more likely to die from unintentional causes such as RTC injuries, older children are more likely to die from intentional causes such as interpersonal violence during the teenage years; these causes are however preventable. The leading causes of non-fatal injuries impacting children have remained unchanged over time, with RTCs being the greatest burden. Resources to prevent child deaths are primarily focused on natural causes, like lower respiratory tract infections, even though the injury burden of children increases with age. It is therefore important to over time strengthen the monitoring of child injury burden in South Africa for all age groups to inform preventative measures. This thesis will focus on the child injury burden of the CoCT. A heat map of mortality has been generated to determine the injury mortality density across the study area for all age groups by linking the GPS coordinates of each small area to each death. The development of this map makes it possible to identify the overall density of injuries by each age group in small areas. Furthermore, heat maps representing the top three leading causes of death are generated across the study area. A spatial regression model is used to determine the association between socioeconomic determinants like the deprivation score, demographic determinants like gender and road-related determinants like speed limit and traffic-related injury burden. While the childhood injury mortality burden in South Africa has significantly increased over time, prioritising its prevention has not gained traction. Therefore, investigating the pattern of child injury mortality over time and identifying the leading causes can play a major role in preventing these deaths. A major cause of child injury burden in South Africa remains RTC; therefore, in addition to determining the pattern of RTC deaths, exploring the morbidity and hospital admission of children suffering these injuries is vital in developing age-appropriate interventions.

3.2 Study Framework

The study framework was adapted from Augustin et al. (2023) as discussed in the literature review chapter (pages 9-32). This section will discuss concepts from the framework and how they are applied in the study. This thesis uses concepts from health equity specifically socioeconomic status in the form of deprivation score. This is defined as attaining the highest

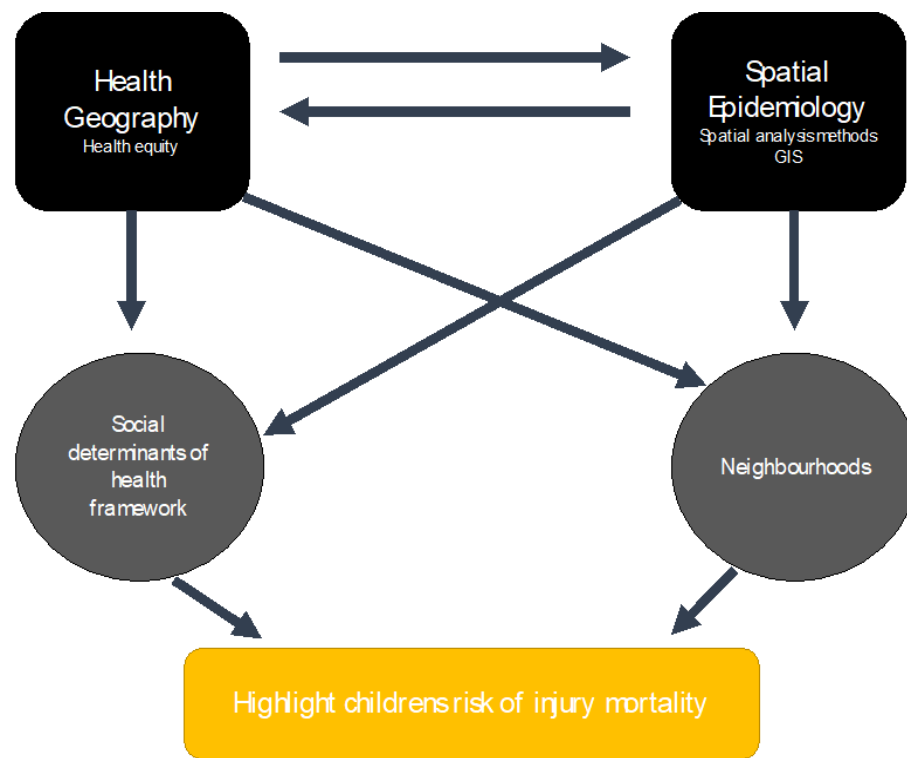
level of health for all people. Additionally, this thesis draws on the concept of spatial epidemiology to assess the impact of location on the risk of child injury mortality. Health equity within a society is challenged by the difference in health experienced by individuals. This difference is caused by various socio-economic factors like income, employment status, and the environmental factors.

Child injury mortality hotspots will be identified through the use of a choropleth map. By using a heat map, their relationship with demographic and SES variables, specifically deprivation score, will be determined.

These concepts are used to determine which factors contribute to the injury burden. Figure 3.1 showcases the interaction of these concepts within a conceptual framework.

Figure 3.1

Interaction of health geography concepts within the conceptual framework



3.2.1 Spatial epidemiology

Epidemiology is the study of factors and processes which impact the health and disease burdens in human populations. This thesis draws on concepts from human geography that provide a spatial understanding of the health of populations, how the disease is spread within an area,

what effects the environment has on health and disease, and access to health care providers (Photis, 2016). It is classified as a qualitative approach with its primary focus being to determine spatial relationships and patterns by exploring the social, cultural, and political contexts for health within a spatial framework (Dummer, 2008).

An example of engaging with concepts of health geography is when young children die or become seriously injured from an RTC in a deprived neighbourhood because there is a lack of safe spaces to play (Wier et al., 2009). These children are forced to play on the street near fast-moving vehicles and are most likely unsupervised (Wier et al., 2009). Since these children do not have access to safe spaces, it places their health and wellbeing at risk. This could easily be prevented by improving infrastructure to create safe spaces.

This PhD thesis highlights the influence of individual background (socio-demographic, economic, etc.) and other external factors and their impact on health status. Individuals with poor health living in deprived neighbourhoods in both affluent (upper-middle class) and non-affluent (low-middle income class) societies have less access to health and other related services (Rosenberg, 2014). To determine the risk of transport-related injury for each suburb of interest in this thesis, the deprivation score is included in the spatial regression model (see Chapter 5, page 80-105).

In South Africa, the affluence of suburbs isn't as clear-cut. In the suburb of Khayelitsha in the CoCT, for example, there are pockets within this community where some households are more affluent than others (i.e., informal homes without clean running water neighbouring formal homes that have plumbing electricity, and a motor vehicle). Khayelitsha was established in 1983 under apartheid rule. Khayelitsha is located on the outskirts of the city and was the "ideal" housing solution for Black Africans that were legally allowed to reside within Metropolitan Cape Town (Cook, 1986). Individuals were provided with core housing; however, sites were available for "illegal individuals" to build shacks. Although Khayelitsha was provided with basic infrastructure like bus routes into the city, a few shops, and a clinic (Cook, 1986) it did not have enough services to be classified as a town. Thus, the middle-income working class who could afford the "core" houses lived alongside those in shacks. The urban design of Khayelitsha remains unchanged, with the suburb remaining inequitable to its residents who live in poverty with inadequate sanitation, limited access to electricity or running water, and

overcrowding. These factors contribute to high injury risk during the developmental stages of an individual.

3.3 Research Objectives

This thesis aims to retrospectively assess the injury mortality in children aged 17 years and younger by using mortuary data recorded between 2011 and 2015 across four sub-health districts of the CoCT namely Klipfontein, Mitchells Plain, Southern, and Western (Figure 3.2).

Figure 3.2

Metro West geographical area of the CoCT which includes 4 sub-health districts: Western, Southern, Klipfontein, and Mitchells Plain



The research of this thesis are:

- i. To describe the injury epidemiology for children aged 17 years and younger from 2011 to 2015 in the CoCT and to generate a heat map highlighting the density of the leading cause of death across the study area.
- ii. To describe the spatiotemporal pattern of transport-related fatalities from 2011 to 2015 in Klipfontein, Mitchells Plain, Southern, and Western sub-health districts and conduct a cluster analysis using a discrete Poisson model and a subsequent negative binomial

(NB) model to determine the relationship between various demographic and socioeconomic risk factors on transport-related injury fatality.

- iii. To analyse both the morbidity and mortality from RTC injury in children in 2014 Klipfontein, Mitchells Plain, Southern, and Western sub-health districts to gain an overall perspective of the RTC injury burden in the study area.

3.4 Research Questions

Three main research questions which have influenced the data used and the analysis conducted to answer the specific questions will each be addressed by a chapter in this thesis. The following questions are addressed by this thesis:

- i. What is the pattern of injury deaths from 2011 to 2015 and where are the densest injury clusters located across the Klipfontein, Mitchells Plain, Southern, and Western sub-health districts ?
- ii. Does time and location impact fatal transport-related burden and which risk factors influences the likelihood of this burden?

What is the pattern of RTC-related morbidity and mortality of children under 13 years of age in 2014 within the Klipfontein, Mitchells Plain, Southern, and Western sub-health district?

3.5 Overall

This thesis will retrospectively assess the injury burden experienced by children aged 17 years and younger between 2011 to 2015 in the City of Cape Town (CoCT). Using routine mortuary data from Salt River Medico-legal Mortuary (SRM) across four sub-health districts of the CoCT namely Klipfontein, Mitchells Plain, Southern, and Western, the injury profile of children will be examined. The child death review (CDR) data will be used to determine mortality profile of children aged 17 years and younger. The Childsafe data will be used to determine the morbidity profile, specifically RTCs, for children younger than 13 years,.

3.6 Definitions

This section provides the definitions for various terms used in this chapter.

- Akaike Information Criterion: Assesses the relative goodness of fit and simplicity of a statistical model.
- Autopsy: A post-mortem examination used to establish the COD or the scope of the disease.
- Burns: An injury to the skin predominately caused by heat or radiation, radioactivity, electricity, friction or contact with chemicals.
- Centroid: The centre of gravity of a geographical unit and does not have to be located within the boundaries of the geographic unit of interest.
- Choropleth map: This map classifies the frequency of values for a given variable for each area of interest (ascending order) by using different colour shades or patterns. It is like a histogram in space.
- Clusters (disease): A group of disease cases or other health-related conditions, like cancer or RTC injury, specified by time and place.
- Cluster analysis: This is a statistical classification technique in which a population is divided into homogeneous groups. Thus, similarities between members belonging to a specific class, or cluster, are high, and similarities between members belonging to different clusters are low.
- Co-ordinates: Longitude, latitude, and elevation of a location.
- Drowning: An event whereby an individual's airway is immersed in liquid leading to difficulty in breathing ultimately resulting in death.
- Exploratory spatial density estimation (ESDA): This is a set of techniques that allows the interactive visualisation and exploration of data in space, to detect patterns. It can also be used to generate hypotheses as well as visually assess model results, diagnostics (visualise patterns of residuals that were determined during the regression process), and data quality control.
- Geocoding: Pinpointing the incidence address based on geographic coordinates onto the map generated.
- Geographic information system (GIS): A tool used to analyse and visualise data normality in the form of a map. Also integrates electronic mapping and database functionality.
- GPS: Global Positioning System (GPS) is a satellite-based navigation system that is comprised of a network of 24 satellites.

- Heat map: A visualisation tool used to identify clusters that have a high concentration of activity or the densest aggregation of cases of the disease
- Injury: Refers to sudden physical damage experienced by the human body suddenly to an amount of energy exceeding the physiological tolerance threshold or in the event of a lack of one of the more vital elements needed for survival, such as oxygen.
- Kernel Density Estimation: A non-parametric method of estimating probability density function and is a continuous random variable that is described as a sum of “bumps”. Each “bump” is assigned to every data point and the size of the “bump” represents the probability assigned to the neighbourhood of values around that data point. Furthermore, each kernel has a bandwidth, which determines the width of the “bump”- i.e., the width of the neighbourhood of values to which probability is assigned. Thus, the bigger the bandwidth results, the shorter and wider the “bump” will be in assigning more probability to the neighbouring values.
- Life expectancy at birth: Refers to the average number of years a newborn is expected to live relative to current mortality rates.
- Morans I statistic: A weighted correlation coefficient used to detect dependence from spatial randomness. This index is based on pattern (spatial) measurements of spatial dependence, which states that nearby features tend to be like each other rather than distant features. This is also termed as spatial autocorrelation (SAC) which provides insights into the processes underpinning a spatial phenomenon.
- Morbidity: Number of individuals suffering from any form of illness relative to place, time, and cause.
- Mortality: Number of deaths by place, time, and cause.
- Motor vehicle crash injury: A collision of a moving vehicle with another object or person.
- Homicide: A physical/chemical action inflicted by another person with the intent to kill by any means.
- [Pneumatic road tube sensor](#): When a vehicle's tires pass over a rubber tube located in the road, these sensors send bursts of air pressure along the rubber tube. This air pressure pulse creates a closed air switch which produces an electrical signal that is transmitted to a counter or analysis software.
- RTC injury: A fatal or non-fatal motor vehicle crash injury; pedestrian injury; cycle, or train injury

- Shapefile: Maps are stored in a shape file format that consists of at least three files with information about the map boundary (.shp), the associated data (.dbf), and a file connecting the two (.shx).
- SES: The social standing or class of an individual or group relative to education level, income, and occupation.
- Spatial autocorrelation (SAC): Correlation of a variable with itself in space. This correlation can be positive (spatial clusters that are high-high or low-low values) or negative (spatial outliers that are high-low or low-high values). Used to determine spatial dependence.
- Spatial data analysis: This form of analysis differs from non-spatial data analysis because the location of an observation is included in the analysis and impacts the outcome. The spatial analysis toolbox includes tools for data visualisation, exploratory spatial data analysis, and spatial econometrics. The latter of the two tools (e.g., spatial autocorrelation tools) goes beyond the visualization of the results on a map as it adds statistical hypothesis tests and spatial regression modelling.
- Spatial dependence: This dependence exists when the value associated with one location is dependent on the values of other locations. Thus, spatial dependence results from spatial interaction effects (e.g., externalities) or from measurement errors (e.g., a mismatch between the scale at which an incident occurs and how the outcome is measured).
- Spatial heterogeneity: Spatial heterogeneity occurs when structural changes of a location exist in a dataset such as differing parameter values or functional forms (e.g., deaths in certain regions might be structurally different from deaths in other regions). Thus, spatial heterogeneity causes heteroskedasticity, a non-constant error variance across areas, especially in the presence of scale-related measurement errors.
- Spatial lag: This variable is the average of all the neighbouring values of a location, whereby the value of each neighbouring location is multiplied by a spatial weight and then the products are summed up. It can be used to compare the neighbouring values with the location of the incident of interest. In this process, locations are defined as neighbours. Thus, the centre of its neighbours is excluded from the definition of neighbours and is set to zero.
- Spatial regression: A statistical model that considers the presence of spatial effects, such as spatial autocorrelation (or spatial dependence) and/or spatial heterogeneity.

- Smoothing: A method used to estimate the underlying, unobservable risk or probability that an event (e.g., death or crime) occurred.
- Standard life expectancy: The average number of years an individual is expected to live in "full health" relative to the number of years lived lost due to disease and/or injury.
- Sudden unexpected death of an infant (SUDI): The death of an infant aged under 12 months that is sudden and unexpected, where the cause was not immediately apparent at the time of death.
- Suicide: The intentional act of taking one's own life.
- Traffic density: The number of vehicles occupying a unit length of a roadway.
- YLD: The measurement of the burden of disease calculated by multiplying the prevalence of a disease/injury by the short- or long-term loss of health associated with the relevant disability.
- YLL: The number of deaths multiplied by the standard life expectancy at the age at which the death occurs.
- Undetermined death: A death where there is an inadequate amount of available information about the circumstances surrounding the death (e.g., partial skeletal remains) or where there is known information that equally supports or conflicts with more than one manner of death. In an instance where there is no clear evidence supporting a specific manner of death (homicide, accident, or suicide) for an unnatural COD it is assigned as an undetermined manner of death.
- Unnatural death: A death that is caused by external causes of injury such as poisoning which can be due to an intentional injury such as homicide or suicide, or death accidentally caused by unintentional injury, like a RTC injury.
- Variance inflation factor: Determines whether collinearity/multicollinearity is present in a model by quantifying the degree of correlation between one predictor and the other predictors of a model.

3.7 Data Sources

This thesis utilises data from the FPS, Childsafe, STATSSA, and South African National Roads Agency SOC LTD (SANRAL). Each data source remains relevant for the reported descriptive and rate analysis addressing the objectives mentioned in section 3.3. These data sources, even those that are outdated, continue to add value in determining the injury profile of children in

South Africa by age group and socioeconomic characteristics of suburbs located in the study area.

Variables analysed included age, gender, manner of death, external cause of injury (method of injury such as burns) and sub-health district. Age was analysed as both a continuous and categorical variable. Age was categorised for children aged 0 to 4 years, 5 to 9 years, 10 to 14 years, and 15 to 17 years. The SRM data was captured in Microsoft Excel and analysed with Stata version 12 (Stata Corp). Descriptive statistics for continuous variables (mean, standard deviation) and categorical variables (proportion, median), where appropriate, were determined. Where appropriate, the characteristics of each injury group were compared using the t-test or Pearson χ^2 statistic. It should be noted that throughout this thesis, unnatural deaths and injury deaths are terms used interchangeably.

Geographical information systems (GIS) is a spatial analytical tool used to develop an effective model by visualising the distribution of diseases and exposures to identify public health issues and their impact in areas at risk (ESRI, 2011). This thesis utilises ArcGIS and QGIS to analyse and visualise the pattern of child injury deaths. GIS tools have been utilised to analyse the spread of infectious and chronic diseases, prevent injuries, and assess the quality and accessibility of health services (ESRI, 2011). In detecting the patterns and distribution of child death, GIS tools are used to highlight areas that require effective child safety programmes and child health, early childhood development, and social services to prevent child deaths.

3.7.1 Forensic Pathology Services

In 2006, SAPS Mortuaries transferred to the health sector whereby the Directorate of Forensic Pathology Services (FPS) was established within the Department of Health. The Inquest Act (Republic of South Africa, 1959) states that all forms of injury deaths are reported to the police and will undergo medico-legal investigation. In the event of a death, the police complete their crime scene investigation, photography, and death declaration. If the death was a result of an unnatural cause, the SAPS Officer or the hospital contacts the closest forensic pathology laboratory. Some of the tasks carried out by the FPS include investigating the scene of death, collecting evidence, assisting SAPS with identification of the deceased, and performing autopsies and post-mortem examination (including specimen collection) of the deceased. All

patient information is collected and stored on a secure server and managed by the IT manager of each facility.

3.7.1.1 Inquest Act (Republic of South Africa)

The Inquest Act (Republic of South Africa, 1959) states that deaths occurring from unnatural causes require an inquest into the cause of these deaths. If any death is suspected to have been caused by means other than natural causes it must be reported to the police. The circumstances surrounding the death are investigated to determine if any person is responsible for the death. A police docket is opened based on the SAPS investigation as either an inquest inquiry, culpable homicide, or homicide. The death is then reported to the magistrate of the district where it occurred. Furthermore, the body of the deceased who has died from an unnatural cause has to be examined by the district surgeon or any other medical practitioner investigating the certainty of the COD.

This thesis's population is children aged 0 to 17 years who have died as a result of unnatural causes in the catchment area (Figure 3.2) serviced by the Salt River Medico-legal Mortuary (SRM) located in the CoCT, South Africa.

3.7.1.2 Study Area, Variables, and Population

Secondary data analysis was performed using all injury-related cases presented to SRM from 1 January 2011 to 31 December 2015 for all children aged 0 to 17 years from four sub-health districts in the CoCT. The four sub-health districts included in the study were Western, Southern, Klipfontein, and Mitchells Plain (Figure 3.2). The study area is 1228.8 square kilometres serving a child population of 2,866,702 based on census data from 2011 to 2015. It consists of urban and peri-urban suburbs that include informal settlements and townships. These sub-districts and periods were included in the study because of data availability.

The CoCT is the oldest city in South Africa and is known as the administrative and economic hub of the Western Cape. The urbanity (i.e., quality or state of urban area) of this city is based on its area size (2,461 km²) and projected population density (4,127,050 people in 2016) of which children (0 to 17 years) represents 7.8 per cent of the population (STATSSA, 2018).

The SRM is an M6 mortuary (intake of >3000 bodies per annum) serving suburbs, informal settlements, and townships across the CoCT and has a catchment area extending from Atlantis to Kommetjie, and from Camps Bay to Mitchells Plain (Mathews et al., 2016). SRM was used because it is one of the largest mortuaries in the CoCT and due to the availability and quality of GPS coordinates provided for each death.

All injury deaths are classified as unnatural deaths and are subject to a post-mortem examination (Republic of South Africa, 2003). In addition, SRM also performs an autopsy when a child has died from a sudden unexpected natural COD. In this thesis, a child is defined as a person under the age of 18 years in accordance with the UNCRC definition (Pinheiro, 2006).

The SRM sub-dataset included deaths of only individuals aged 0 to 17 years, with cases identified as having a natural COD (n=1738; 66.8 per cent) excluded.

Table 3.1

Represents the projected population estimates by sub-district, age category, and year. 2011-2015; Metro West, CoCT

		Klipfontein (n)	Mitchells Plain (n)	Southern (n)	Western (n)	Total (n)
2011	Under1 Year	7282	10985	7821	7881	33969
	1-4 years	26927	41338	29636	29170	127071
	Under 5 years	34403	52622	37619	37246	161889
	5-9 years	32006	47193	36772	32403	148375
	10-14 years	33818	46071	39979	31385	151253
	15 - 17 years	20176	27159	24267	18586	90188
	Total	154611	225368	176095	156671	712745
2012	Under1 Year	7440	11351	7959	8237	34988
	1-4 years	27012	42034	29837	30036	128919
	Under 5 years	34453	53628	37796	38273	164150
	5-9 years	31880	47708	36879	33152	149619
	10-14 years	33121	45543	39546	31409	149620
	15 - 17 years	19903	26943	24140	18696	89682
	Total	153808	227208	176158	159803	716978
2013	Under1 Year	7126	10989	7680	8102	33897
	1-4 years	26989	42556	29923	30784	130253
	Under 5 years	34238	53732	37681	39009	164659
	5-9 years	31962	48531	37226	34126	151844
	10-14 years	32443	45021	39115	31426	148004
	15 - 17 years	19756	26895	24165	18929	89744
	Total	152513	227724	175789	162375	718401
2014	Under1 Year	6902	10756	7443	8042	33142
	1-4 years	26882	42938	29921	31435	131176
	Under 5 years	33820	53744	37337	39502	164403
	5-9 years	32206	49604	37761	35289	154861
	10-14 years	31748	44454	38644	31400	146247
	15 - 17 years	19574	26795	24141	19121	89630
	Total	151132	228292	175247	164788	719459
2015	Under1 Year	6678	10511	7207	7967	32363
	1-4 years	26688	43177	29815	31985	131665
	Under 5 years	33324	53610	36902	39884	163720
	5-9 years	32439	50668	38285	36461	157853
	10-14 years	31257	44154	38404	31554	145369
	15 - 17 years	19308	26576	24003	19220	89106
	Total	149694	228696	174616	167070	720076

Projected population estimates (Table 3.1) for the CoCT were determined using the Actuarial Society of South Africa 2003 model (Western Cape Provincial Department of Health, 2014) to calculate age-specific rates per 100,000 population.

To estimate the injury mortality burden of children, the Global Burden of Disease methodology (Murray et al., 1996) was used to determine injury distribution and premature mortality by COD, age group, and gender. COD data was coded as defined by SRM. Fatal interpersonal and self-inflicted injuries were referred to as homicides and suicides respectively (Norman et al., 2010).

Figure 3.3

Map representing average population of children in Metro-West CoCT 2011-2015: 0-4 years, 5 - 9 years, 10 - 14 years, 15 - 17 years. 2011-2015; Metro West, CoCT

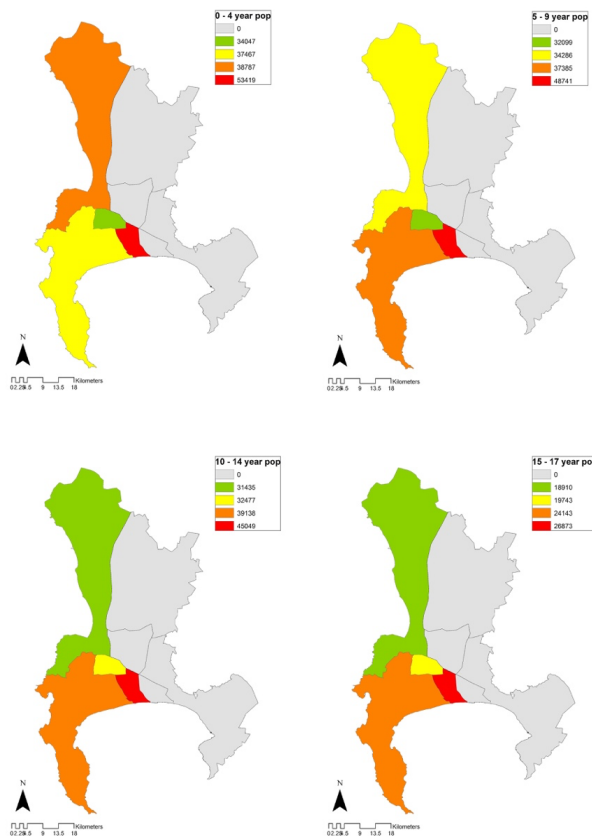


Figure 3.3 represents the average population over five years (2011 to 2015) highlighting the average number of children by age group in each sub-health district.

3.8 Outline of Subsequent Chapters

- i. Epidemiology of injury-related mortality in children younger than 18 years living in Metro West, CoCT, from 2011 to 2015. Injury mortality in children aged 17 years and younger by age, injury type, and gender will be determined followed by premature mortality estimates. A heat map will be used to highlight the density of all injuries by location across the Metro West, CoCT.
- ii. Spatial analysis of transport-related child injury mortality in the CoCT over time. All transport-related child deaths will be clustered in space and time using SatScan

followed by creating regression models in R to assess the risk of an incident influenced by various demographic and socioeconomic factors.

- iii. Morbidity and mortality from RTC in children in the CoCT in 2014. The characteristics of fatal and non-fatal RTCs within the Metro West will be determined using descriptive analysis in STATA. YLD estimates will be determined using the methodology proposed by Haagsma et al. (2016). To determine the impact of various risk factors on hospital admission for non-fatal RTC injuries, a multiple regression analysis will be performed.

- a. PhD Candidate's Role in Published Article

This is a thesis by manuscript and not a thesis based on a compilation of prior published work. The thesis consequently includes some limited content from the following publication arising from the FPS and Childsafe data. The PhD candidate's role in the paper is clarified:

Albertyn, Z., Mathews, S., Coetzee, D. and Bastiaan Van As, A., 2019. Morbidity and mortality from road traffic crashes in children in Metro West, City of Cape Town–2014. *International Journal of Injury Control and Safety Promotion*, 26(1), pp.115-123.

- The PhD candidate with the principal investigator was responsible for the initial concept.
- The PhD candidate was responsible for cleaning the data, data analysis, constructing the first draft of the paper, incorporating co-author comments, and final submission to the journal, with the reviewer's comments incorporated.
- The PhD candidate contributed to the write-up of the paper and approval of the final version.

3.9 Ethical Considerations

The study was approved by the Human Research Ethics Committee of the University of Cape Town's Faculty of Health Sciences (Reference: 063/2016) (Appendix I).

This thesis adheres to the ethical principles outlined in the Declaration of Helsinki (Helsinki, 2013). Firstly, the study poses no risk to patients from the Child Death Review (CDR) as they are deceased. Secondly, the study primarily involved secondary data analysis of death records and child death review data; therefore, there is no active engagement with patients. Thirdly, the privacy and protection of the patients' data are maintained since all the data is collected anonymously with no identifying details captured. An extensive knowledge of the scientific literature as well as other relevant sources of information were gathered to align the study to the general scientific principles of performing medical research involving human subjects.

3.9.1 Protection of Privacy and Confidentiality of Patient Data:

Informed consent is an interactive communication between the researcher and the study subject and is the primary mechanism used to secure the study subjects' consent to participate in a study (Helsinki, 2013). Informed consent is used to educate the potential study subjects about the research to be conducted. This ensures that study subjects understand what the expectations are, the benefits, and potential risks that could incur with their participation.

In this PhD study, the study subjects are mainly deceased, and records will be reviewed following their death at the SRM mortuary. Therefore, informed consent is not required. The data identifier is the mortuary number; and even though GPS co-ordinates are used, the exact time and date of death is not published. Therefore, the probability of disclosing the identity of any study subjects is reduced. Consent for the use of Childsafe data was not required because the database itself has ethical clearance. The data identifier was trauma unit record number; the exact date and time of the injury or admission is not published.

The study's subjects' information was extracted from post-mortem reports of the SRM catchment area stored in the FPS intranet known as Live-Link. To further secure the confidentiality of the subjects' personal information such as their identification number and full name, the information systems manager of Live-Link generated this dataset. The coded dataset was viewed and extracted by the researcher (PhD candidate) from a desktop at the Department of Forensic Medicine, University of Cape Town, with the permission of Prof. Lorna J Martin.

Chapter 4: Epidemiology of injury related mortality in children under 18 years of age in Metro West, City of Cape Town: 2011-2015

4.1 Background

The death of children across the globe is driven by a combination of natural causes of death (COD), and increasingly various forms of injury. COD could result from cases such as neonatal conditions due to prematurity and birth complications, infectious diseases such as LRTIs and diarrhoeal disease. Injuries on the other hand could result from RTC and violent crime such as homicide as children are growing up (Institute for Health Metrics and Evaluation, 2021). Over the past decade in LMICs, a decline in natural causes of death can be observed due to improvements in water and sanitation services as health programmes are put in place to prevent these deaths (Hug et al., 2017). However, even though there is a decline in natural COD incidence among children, LMICs continue to report an increase in injury-related deaths (Institute for Health Metrics and Evaluation, 2021).

Injuries are described as being either unintentional (without purposeful intent and resulting in death or disability), such as RTC and drowning, or intentional (with purposeful intent resulting in death or disability), such as homicide and suicide (Institute for Health Metrics and Evaluation, 2021). Globally, the injury burden for children decreases as children become older, with children younger than 10 years mainly dying from unintentional injuries such as RTCs while those older than 10 years being more at risk of dying from intentional injury such as suicide or homicide.

In 2019, the global injury mortality rate for children younger than 5 years was 31.5 per 100,000, with RTCs (5.8 per 100 000) being the leading cause followed by drowning (5.5 per 100,000) (Institute for Health Metrics and Evaluation, 2021). Children younger than 5 years are also the greatest contributors to injury premature mortality (YLL) at 2,741 YLL per 100,000, with deaths predominantly from RTC (502 YLL) followed by drowning (475 YLL). In 2019, the global injury mortality rate for children aged 5 to 14 years was 13.6 per 100 000 children with RTC injury (4.2 per 100 000) being the leading cause (Institute for Health Metrics and Evaluation, 2021). Furthermore, in 2019 the global pattern of premature mortality for children aged 5 to 14 years was 1,075 YLL per 100,000 children who predominantly died from RTC (337 YLL per 100,000 population) followed by drowning (224 YLL per 100,000 population) (Institute for Health Metrics and Evaluation, 2021).

South African children's overall injury mortality profile, with regard to RTCs and homicides, follows a similar pattern to the other UMICs. In 2012, using data from the 2009 IMS, the second national burden of disease study for South Africa found that most child injury deaths occurred in children younger than 5 years followed by those who were 15 years and older (Pillay-van Wyk et al., 2016). Similarly, Prinsloo and colleagues using data from the IMS 2017 data found that most of these children died of either homicide or RTCs (Prinsloo et al., 2021). Studies have found that the pattern of injury-related fatality for children at the provincial and nationwide level was similar. In the Gauteng Province, children aged 6 to 12 years died predominantly as pedestrians, with children aged 12 years more likely to die of homicide due to sharp force injury (Pretorius & Van Niekerk, 2015). This suggests that very young children and adolescents are more likely to be involved in a fatal injury incident than children of other ages. In 2009, the homicide mortality rate for South African children was 13.2 per 100 000 in the those aged 15 to 17 years (Mathews et al., 2016), which was 2.2 times higher than the global estimates in 2010 and 2019 (Institute for Health Metrics and Evaluation, 2021). Other injury types such as suicide do not impact all children but mainly those older than 9 years (Prinsloo et al., 2021).

Injury-related deaths are preventable and predictable and are closely linked to socio-economic and environmental conditions such as low caregiver educational attainment, lack of good work opportunities for caregivers, and exposure to unsafe living conditions such as fire or dangerous traffic (Giashuddin et al., 2009; Hussey, 1997). In considering the widespread occurrence of interpersonal violence in South Africa, several factors are to be considered; these include: age and gender (e.g., adolescent males are more likely to die from homicide compared to females of the same age (Matzopoulos et al., 2015); behavioural factors; and societal risk factors such as low SES, living in violent neighbourhoods, easy access to guns, alcohol, and drugs (Myers et al., 2007). In Brazil, it was found that there were higher homicide rates in children (30.4 homicides per 100,000) in informal settlements where individuals with lower incomes and educational levels reside (Santos et al., 2006). Similarly, in Cape Town, South Africa, deprived townships such as Khayelitsha and Nyanga are affected by poor socio-economic conditions. The deprived communities continually report an increase in the risk of homicides, especially among males (Norman et al., 2007 2003, Groenewald et al., 2017).

The CoCT continues to be spatially segregated by race. This is an outcome of the apartheid era which generated a divide between (previously) affluent white areas and the socio-economically disadvantaged and overcrowded township areas that encompass most of the previously disadvantaged population (Fitzpatrick & LaGory, 2002 2005). Mortality across the city varies, with Khayelitsha, the most resource-limited sub-health district, having the highest mortality rate due to injury (153.4 per 100, 000population) compared to the more affluent Southern health district (78.8 per 100,000population) (Groenewald et al., 2017). Despite literature suggesting that there are several socio-economic risk factors influencing the likelihood of injury occurring, there is limited research performed in South Africa to support this claim. A study by Ataguba et al. (2011) using data from the general household survey found that 82.5 % of the population that suffered some forms of injury were from the poorest 80 % of the population.

The most common forms of unintentional injury are RTCs, which are explored in more detail in chapter 6 of this thesis, followed by fire-related, and drowning injuries. Nearly 14 % of global RTC deaths occur in children younger than 15 years (Institute for Health Metrics and Evaluation, 2021). Several risk factors influence the likelihood of a child being involved in a fatal RTC injury. These include physical development (e.g., small size); cognitive development, specifically their inability to make safe decisions when crossing the road (Pitcairn & Edlmann, 2000); gender (males are more likely to be involved in RTC compared to females) (Mathers et al., 1999); young drivers (inexperienced drivers aged from 16 to 19 years are more likely to cause a motor vehicle accident compared to drivers aged 20 years and over with the same driving experience (Mayhew et al., 2003) and are more likely to drive while under the influence of alcohol or drugs (Keall & Frith, 2004); and lack of supervision especially in young children (Waylen & McKenna, 2008). In the Western Cape Province between 2010 and 2016, there was a stable trend in transport-related deaths involving children, with pedestrian incident being the leading cause (Evans J, 2018).

In areas with poor housing, unemployment, and a high density of children under 14 years, the incidence of fire injuries is higher because these households are more likely to use wood fire or paraffin (Van Niekerk et al., 2006). Further contribution to the incidence of fire-related injuries is the rapid rate of urbanisation; poor planning of infrastructure, and the proliferation of large numbers of informal dwellings constructed with flammable materials such as wood;

dwellings built in close proximity; and using highly flammable substances such as paraffin as the primary cooking and heating method (Reichenheim & Harpham, 1989; Rizvi et al., 2006). All these factors greatly increase the risk of fire injury in informal settlements.

In 2019, the drowning rate in children younger than 5 years in LMICs (4.6 per 100, 000) was nearly six-times higher than HICs (0.8 per 100,000). Globally, the highest drowning mortality rates occurred in children younger than 5 years. However, the gender difference in drowning mortality is greatest in older children, with males more likely to die from drowning in both HICs and LMICs as these children are likely to be unsupervised (Howland et al., 1996; Peden et al., 2004). Another important risk factor that impacts the pattern of child drowning is the type of water body (e.g., pool, sea, dam, river, lake, bucket of water) that the child is exposed to. In LMICs, studies have found that children older than 9 years are at a higher risk of drowning while engaged in daily activities such as collecting water, washing clothes in a body of water, or crossing a river to get to school (Celis, 1997; Hyder et al., 2003). In comparison, children living in UMICs and HICs are more likely to drown in a swimming pool (Kobusingye et al., 2001). However, most children in South Africa drown in or around their home; for example, in informal settlements where households share communal toilets, individuals store water in buckets in the evening for safety reasons, which increases the likelihood of young children drowning in these “bucket toilets” (Anderson et al., 2002). On the other hand, unsupervised children in HICs are likely to drown in a swimming pool because there is inadequate fencing around it (Celis, 1997).

To reduce child injury mortality, child safety must be prioritised and made central to strategies to reduce child injuries in communities. Several SDGs (3, 4, 5, 11, 16, 17) target improved child safety, specifically 3.2, which aims to halve the number of RTC deaths and injuries by the year 2030, and 16.1 which aims to reduce all forms of violence and related death rates (United Nations, 2019). Target 11.7 aims to provide, by the year 2030, universal access to safe, inclusive, accessible, and green public spaces, particularly for women and children, older persons, and persons with disabilities (United Nations, 2019). To ensure that these development goals are effectively implemented and monitored at the country level, governments need to be actively involved in setting measurable targets that articulate the SDG targets and consider the implementation of appropriate evidence-based interventions. There is a need to strengthen routinely collected data and prospectively monitor in-country progress. South Africa faces the

challenge of monitoring the progress of the SDGs to report to the United Nations and having all the appropriate routine data sources to measure the targets set by the government.

Being able to identify all deaths occurring both in and out of health facilities as well as the cause and manner of death, will improve the quality and completeness of child injury mortality data. According to the Inquest Act in South Africa, every unnatural death and sudden unexpected death must undergo an autopsy to determine the COD regardless of whether or not there is an individual responsible for the death (Republic of South Africa, 1959). The South African FPS performs autopsies for all unnatural deaths with the data routinely collated. To reduce preventable deaths, this information should be reported annually to both the public and key stakeholders such as policymakers and non-governmental organisations. The National Statistics Department of South Africa, Statistics South Africa, routinely misclassifies manner of injuries (like homicide, suicide etc.) as “other unintentional”. This misclassification results from the ICD-10 coding convention that dictates injury deaths without an unknown intent default to unintentional deaths. To address this, South Africa’s national injury mortality surveillance system (NIMSS) was developed by the South African Medical Research Council to improve the completeness and quality of injury mortality data at a national and local level (Matzopoulos, 2002). However, the NIMSS data became more urban biased from 2005 to 2008 resulting in a decline in the capacity to monitor the data in South Africa due to a lack of investment (Matzopoulos et al., 2013). As such, no data has been released since 2008. However, in 2009 the injury mortality survey (IMS) was conducted with fieldworkers collecting data from a national representative sample of mortuaries. This was followed by two additional IMSs conducted in 2017 and in 2020. The system aimed to provide quality epidemiological data to be used by the government to inform policy and appropriately allocate funding in order to effectively reduce the injury burden. The latest report that was released in 2021 utilised nationwide mortuary data and highlighted the injury burden across all ages. The system can integrate with other related surveillance data such as GIS spatial data, to facilitate an in-depth analysis of the high injury burden impacting South Africa (South African Medical Research Council, 2016). This will ensure that injury statistics are released in a timely manner. This will ensure the timeous turnaround release of injury statistics. Although STATSSA publishes a COD report annually, this is derived from death certificates and underestimates the overall mortality profile at the national and local level (Statistics South Africa, 2019). Furthermore, this report does not determine mortality rates but only the absolute number and

proportion of deaths. Evans and colleagues, determined the injury mortality rate across health sub-districts by age and cause and used mortuary and population data, providing a clearer picture of the injury burden within the province (Evans J, 2018). However, there has not been a follow-up to these results as the provincial injury mortality surveillance system was halted in 2015 by the Department of Home Affairs. This thesis will add to this routine analysis by providing additional in-depth analysis on the pattern of child injury mortality over time while also including the suburb where the injury occurred. It will give a clearer picture of where and which interventions are needed to reduce this burden.

This thesis aimed to use mortuary data from SRM to describe the injury mortality of children younger than 18 years (0-17 years) in Metro West from 2011 to 2015. The data included age, gender, the geographic location where the injury occurred, manner of death, and external cause of injury. The CoCT is divided into Metro East and Metro West, with Metro West comprising of four of the eight health sub-districts, namely Klipfontein, Mitchells Plain, Southern, and Western.

4.2 Specific Objectives

This chapter aims to describe the injury mortality of children aged 17 years and younger by age, manner of death, COD, and gender from 2011 to 2015 across four sub-health districts serviced by SRM of FPS. Additionally, a heat map highlighting areas with the densest fatal injury incidences is generated. The apparent leading manner of death over five years (2011 to 2015) by each of the four sub-health districts of interest is mapped. These sub-health districts are Klipfontein, Mitchells Plain, Southern, and Western.

Klipfontein includes Nyanga, which has the highest documented homicide rate in the country (Crimestats, 2021). All four of these health sub-districts have many informal settlements located alongside lower and middle-income communities and are characterised as having inadequate housing, poor sanitation, high levels of unemployment, and poverty (South African Cities Network, 2011); all of which play a significant role in increasing children's risk of injury.

4.3 Specific Methods

A secondary data analysis was performed using the FPS BIM and where information was missing, the dataset used by Evans and colleagues (Evans J, 2018) was cross-referenced. The

FPS data used included all children aged 0 to 17 years who have died from an injury-related death between 1 January 2011 and 31 December 2015. Injury deaths were classified by intent as either intentional, unintentional, or undetermined. They were further categorised into apparent manner of death (MOD) namely homicide, transport, suicide, and other unintentional. The MOD was classified into external causes of injury, namely sharp force/stabbing, firearm, hanging, road traffic pedestrian, motor vehicle passenger, cycle, train, driver, fire/burns, drowning, falls, electrocution, and suffocation.

Variables analysed in the study included age, gender, manner of death, method of death, and place of incident (sub-health district). Data was analysed with Stata version 12 (Stata Corp). Age was only analysed as a categorical variable and was categorised for children aged 0 to 4 years, 5 to 9 years, 10 to 14 years, and 15 to 17 years. Rate ratios were calculated by using a 95 % confidence interval and any result with a $p < .05$ was considered significant for all analyses.

Age-specific mortality rate was determined by dividing the number of injury deaths by population count over 2011-2015 for each age category, manner of death, and external causes of injuries.

Premature mortality was calculated in years of life lost (YLL) with no age-weighting, 3 % time discounting, and standard life expectancies (LE) for males and females derived from the Coale-Demeny Model Life Tables West (level 25 for males and level 26 for females) (Aragón et al., 2008; Murray et al., 1996; Neethling et al., 2017). Figure 4.1 presents the R function used to determine YLLs for this thesis (Aragón et al., 2008).

Figure 4.1

R function used to determine YLL's for this thesis

```

yll <- function(number.deaths, average.age.death, model.life.expectancy,
discount.rate = 0.03, beta.constant = 0.04,
modulation.constant = 0, adjustment.constant = 0.1658){
##abbreviate inputs
N <- number.deaths; a <- average.age.death
L <- model.life.expectancy; r <- discount.rate
b <- beta.constant; K <- modulation.constant
CC <- adjustment.constant
##do calculations
if(discount.rate==0){
N*(K*CC*((exp(-b*a))/b^2)*((exp(-b*L))*
(-b*(L+a)-1)-(-b*a-1))+((1-K)*L))
} else {
N*(K*((CC*exp(r*a))/(-(r+b)^2))*((exp(-(r+b)*(L+a))*(-(r+b)*
(L+a)-1))-exp(-(r+b)*a)*(-(r+b)*a-1))+((1-K)/r)*((1-exp(-r*L))))
}
}

```

Discounting is a social-value choice which when applied to YLL calculation measures the net present value of years of life lost in the future. This implies that people place a higher value on a year of life lived in the present compared to a year of life lived in the future (Neethling et al., 2017).

Age weighting is a social-value choice that reflects a social preference of people to assign more value to a year lived in their economically active age (young adults) than to a year lived in their childhood or old age. This thesis did not use age-weighting for the YLL since it is unethical to value the life of young adults over other age groups (Neethling et al., 2017).

A heat map was used to visualise the spatial distribution of all forms of apparent manner of injury deaths from 2011 to 2015 for children aged 0 to 17 years at the sub-health district level by utilising the location and distribution of each point injury data. Firstly, each case was mapped in QGIS and aggregated according to manner of death by creating clusters from each injury point, with each manner highlighted according to its distribution. Secondly, the heat map was generated to determine high and low densities of injury clusters across the study area for children younger than 18 years from 2011 to 2015. Each injury point was analysed to create an interpolated surface that showcased the density of injury incidents.

There were 35 observations that had missing apparent manner of death information of which 16 had no gender information. However, all 953 observations had age data.

4.4 Data Sources

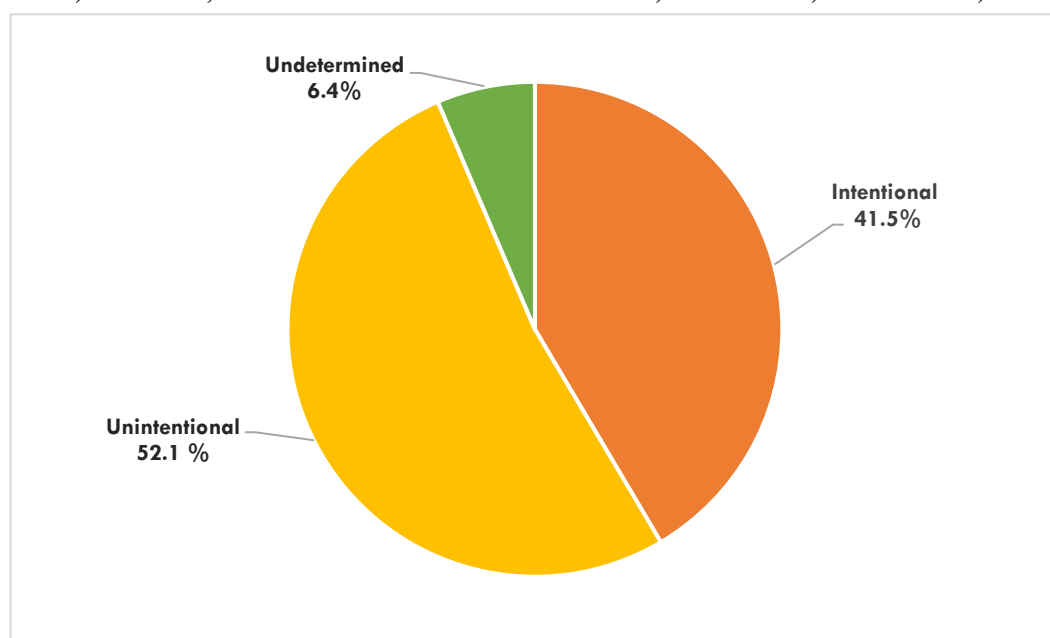
FPS was the main data source utilised in this objective; specifically for the variables (Turner & McClure, 2003), location of injury and mentioned time frame (2011 to 2015).

4.5 Results

There was a total of 935 child injury deaths representing all the sub-health districts. The unintentional intent accounted for 52.1% of the total, while the intentional and undetermined intent accounted for 41.5% and 6.4%, respectively. (Figure 4.2).

Figure 4.2

The intent of death represented as a percentage between 2011-2015; Klipfontein, Mitchells Plain, Southern, and Western Sub-Health Districts, 2011-2015; Metro West, CoCT



The injury mortality rate varies across the age groups over time (Figure 4.3). Children aged 15 to 17 years had the highest mortality rate over time compared to all other children while those aged 5 to 9 years had the lowest mortality rate. The mortality rate for children younger than 5 years was similar between 2011 and 2013; however, this peaked in 2015 (53.1 per 100,000 children). The mortality rate for children aged 5 to 9 years and 10 to 14 years was stable over time compared to children aged 15 to 17 years, who had a mortality rate that consistently increased over time and peaked in 2015 (86.4 per 100,000).

Figure 4.3

Injury mortality rate (per 100,000 population) by age group over 2011-2015; Metro West, CoCT

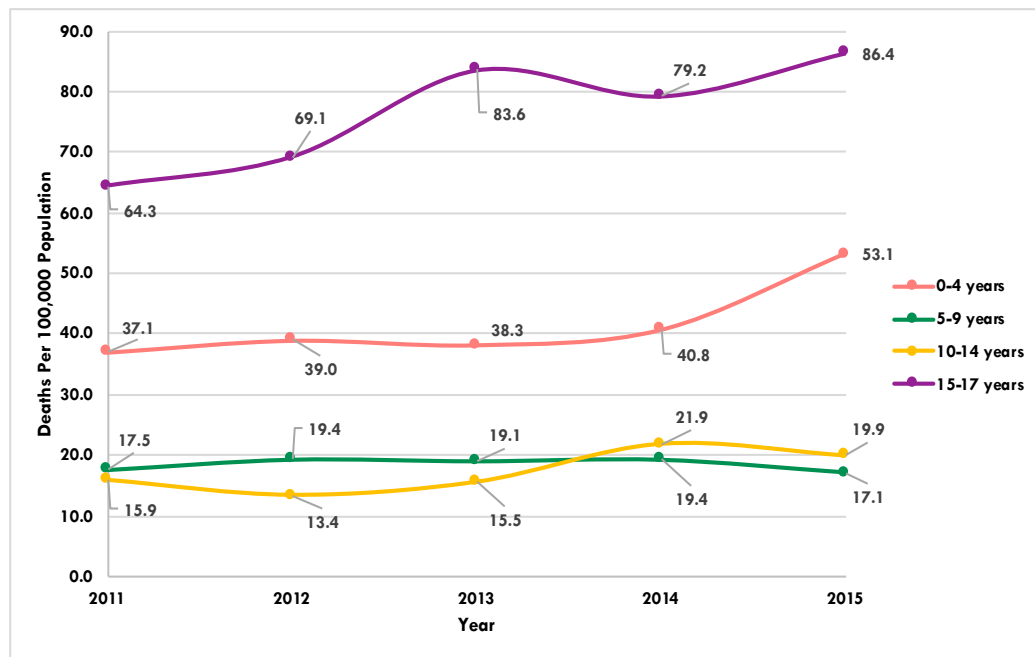
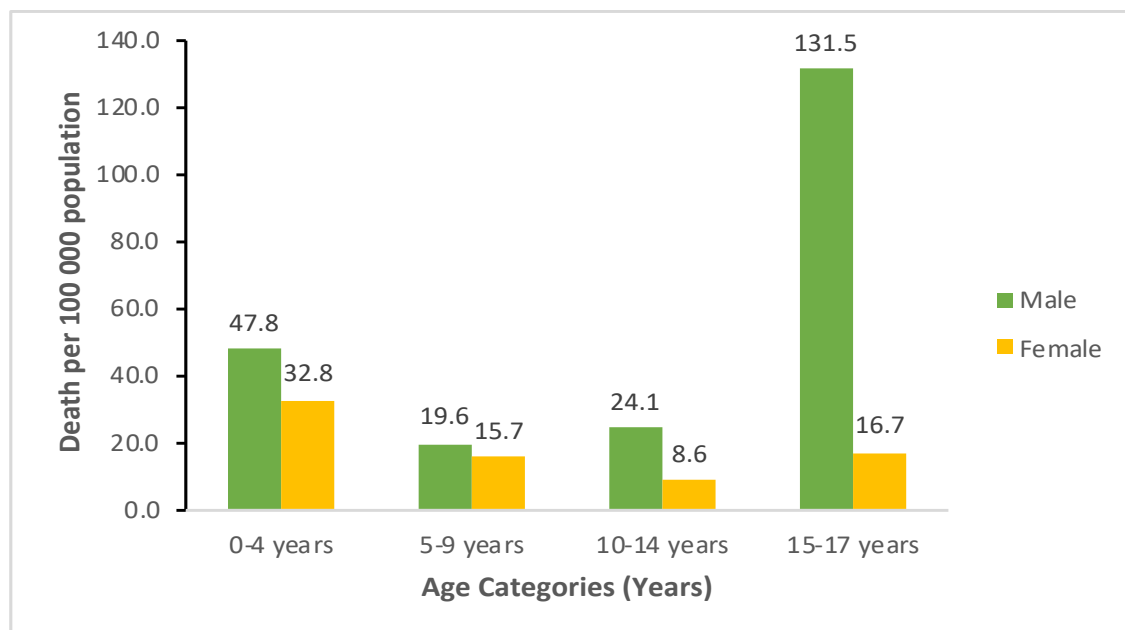


Figure 4.4

Injury mortality rate per 100 000 children 0-17 years by age category and gender, 2011-2015; Metro West, CoCT



Across all age groups, males had a higher mortality rate compared to females, with the greatest difference observed in the 15 to 17-years-old age group which had 7.8 male deaths to every 1 female injury death (Figure 4.4).

The age specific mortality rate from all external causes in Metro-West CoCT was 26.3 per 100 000 children 17 years and younger. The mortality rate among males was significantly higher (36.4 per 100,000) compared to females (14.8 per 100,000) in children younger than 17 years ($p < .0001$); a 2.46 times greater risk for male deaths (Table 4.1). Unintentional injury deaths accounted for 51.3 % (n=481) of cases across all age groups. However, at a rate of 9.8 per 100 000 children younger than 17 years, homicide was the leading apparent manner of death .This accounted for 37.6 % (353/937) of all injury deaths with the male homicide rate (15.9 per 100,000) higher than the female rate (3.2 per 100,000).

For children younger than 17 years, the transport (includes road traffic pedestrian, motor vehicle passenger, cycle, train and driver) mortality rate was 6.4 per 100,000, with the pedestrian rate (4.4 per 100,000) contributing the most to this burden. At 5.9 per 100,000, males were at a significantly greater risk than females (2.7 per 100,000) (RR=2.2; $p < 0.0001$). Other unintentional injury mortality rate was 7.4 per 100,000 children 17 years and younger, with fire injuries (3.4 per 100,000) contributing the most to this burden followed by drowning (1.9 per 100,000).

Table 4.1

Apparent manner of death and major external causes of mortality for children 0-17 years by gender; 2011-2015; Metro West, CoCT

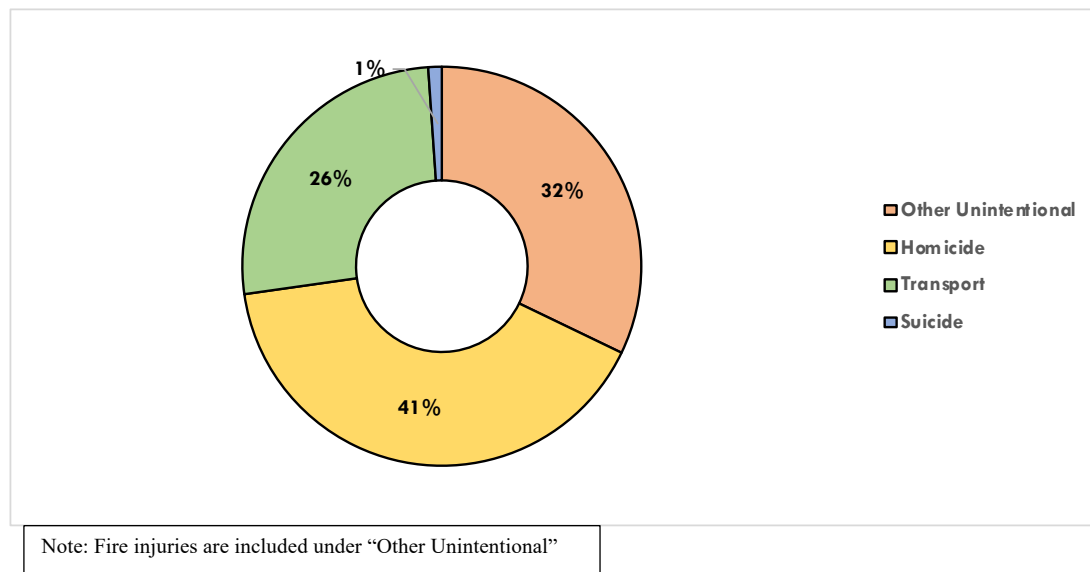
Apparent manner and external causes of death	Males		Females		Total Persons		RR (95 % CI)
	No. (95 % CI)	Mortality rate per 100 000 population (95 % CI)	No. (95 % CI)	Mortality rate per 100 000 population (95 % CI)	Male/Female No. (95 % CI)	Mortality rate per 100 000 population (95 % CI)	
All injuries	664 (457.8 - 831.6)	36.4 (25.1 - 44.2)	260 (201.1- 352.4)	14.8 (11.1-19.4)	937 (394.6 - 1488.2)	26.3 (17.5 - 44.6)	2.4 (2.1-2.8)
Intentional injuries	312 (176.8 - 470.9)	17.1 (9.6 - 25.8)	70 (54.8 - 92.7)	3.9 (3.1 - 5.2)	385 (267.5 - 485.9)	10.8 (7.4 - 13.5)	4.3 (3.3-5.7)
Homicide	291 (231.5 - 327.2)	15.9 (12.6- 17.8)	56 (49.0 - 67.4)	3.2 (2.8 - 3.8)	347 (282.3 - 396.2)	9.8 (7.8 - 11.0)	5.1 (3.7-6.8)
Sharp force / stabbing	152 (134.1 - 157.2)	8.3 (7.3 - 8.5)	12 (0.38 - 12.2)	0.6 (0.02 - 0.67)	164 (145.6- 170.6)	4.6 (4.0 - 4.8)	13.4 (7.3-27.5)
Firearm injuries	92 (68.5 - 96.8)	4.8 (3.6 - 5.3)	16 (1.4 - 28.3)	0.9 (0.08 - 1.6)	108 (83.9 - 118.4)	3 (2.3 - 3.2)	5.4 (3.8-9.2)
Other	47 (36.6 - 51.7)	0.4 (0.3 - 0.44)	28 (3.6 - 34.9)	0.26 (0.18 - 0.38)	75 (59.6 - 84.3)	0.4 (0.18 - 0.5)	1.5 (0.9-2.5)
Unknown	1 (0.69 - 1.8)	0.14 (0.11 - 0.16)	1 (0.69 - 1.8)	0.14 (0.11 - 0.16)	2 (1.4 - 3.6)	0.06 (0.042 - 0.11)	0.9 (0.01-76.4)
Suicide	21 (11.9 - 37.2)	1.2 (0.68 - 2.12)	14 (3.2 - 21.9)	0.8 (0.62 - 1.26)	35 (30.2 - 42.7)	0.9 (0.71 - 1.68)	1.4 (0.7-3.1)
Hanging	13 (5.4 - 25.5)	0.7 (0.41 - 1.4)	3 (2.8 - 4.2)	0.2 (0.19 - 0.28)	16 (6.6 - 31.4)	0.4 (0.23 - 0.78)	4.2 (1.2-23.1)
Other	8 (1.6 - 13.3)	0.1 (0.04 - 0.19)	11 (3.6 - 19.8)	0.6 (0.20 - 1.08)	19 (15.2 - 31.6)	0.5 (0.10 - 0.83)	0.7 (0.2-1.9)
Unintentional	318 (196.6 - 542.1)	17.4 (10.8- 29.6)	162 (100.1 - 276.2)	9.2 (5.6 - 15.6)	480 (297.4 - 819.9)	13.4 (8.2 - 22.8)	1.9 (1.5-2.3)
Transport	154 (100.6 - 274.8)	8.9 (5.8 - 15.8)	62 (14.0 - 83.7)	3.5 (0.8 - 4.7)	217 (52.1 - 310.6)	6.4 (1.4 - 8.6)	2.4 (1.8-3.3)
Road traffic pedestrian injuries	108 (41.7 - 190.7)	5.9 (2.2 - 10.4)	48 (36.6 - 66.6)	2.7 (2.1 - 3.9)	156 (60.2 - 275.1)	4.4 (1.7 - 7.7)	2.2 (1.5-3.1)
Motor vehicle passenger injuries	27 (12.4 - 49.8)	1.4 (0.6 - 2.6)	11 (9.3 - 16.0)	0.6 (0.51 - 0.8)	38 (17.4 - 70.1)	1.1 (0.5 - 2.0)	2.3 (1.1-5.3)
Other	19 (8.4- 47.3)	0.9 (0.31 - 1.8)	3 (1.9 - 2.6)	0.2 (0.19 - 0.26)	22 (9.1 - 51.2)	0.6 (0.20 - 1.18)	11.6 (2.8-101.9)
All road traffic injuries	135 (84.4 - 237.6)	3.7 (2.3 - 6.5)	59 (44.8 - 81.1)	1.6 (1.2 - 2.2)	194 (157.7 - 240.7)	2.7 (2.2 - 3.4)	2.2 (1.6-3.1)
Other unintentional injuries	164 (72.2 - 275.5)	8.9 (3.9 - 14.9)	99 (68.0 - 144.0)	5.6 (3.8 - 8.1)	263 (116.6 - 445.2)	7.4 (3.2 - 12.4)	1.5 (1.2-2.1)
Fire/burns	60 (31.8 - 114.3)	3.8 (1.8 - 6.2)	47 (36.1 - 84.6)	3.1 (2.0 - 4.8)	107 (57.6 - 207.1)	3.4 (1.8 - 5.6)	1.2 (0.8-1.8)
Drowning	51 (18.6 - 96.6)	2.8 (1.0 - 5.2)	16 (14.6 - 23.1)	0.9 (0.8 - 1.2)	67 (24.7 - 128.1)	1.9 (1.2 - 3.5)	2.9 (1.6-5.4)
Falls	10 (4.8 - 19.8)	0.6 (0.3 - 1.2)	2 (1.9 - 3.0)	0.28 (0.006 - 0.4)	12 (5.8 - 23.7)	0.4 (0.19 - 0.8)	4.8 (1.03-45.6)
Electrocution	10 (5.4 - 19.4)	0.6 (0.3 - 1.2)	3 (2.8 - 4.6)	0.68 (0.034 - 1.0)	13 (7.0 - 25.3)	0.4 (0.2 - 0.8)	3.2 (0.8-18.3)
Suffocation/threats to breathing	17 (7.1 - 33.2)	1 (0.4 - 1.7)	13 (3.8 - 24.4)	0.8 (0.2 - 1.3)	30 (8.9 - 56.9)	1 (0.25 - 1.6)	1.2 (0.6-2.6)
Other	11 (2.4 - 18.2)	0.6 (0.13 - 0.4)	11 (2.4 - 18.2)	0.4 (0.08 - 0.6)	22 (5.0 - 38.2)	0.4 (0.08 - 0.6)	0.9 (0.4-2.4)
Unknown	1 (0.9 - 1.9)	0.06 (0.0008 - 0.24)	1 (0.9 - 1.9)	0.06 (0.0008 - 0.24)	2 (1.9 - 3.9)	0.06 (0.0008 - 0.24)	0.9 (0.01-76.4)
Undetermined intent	32 (18.9 - 53.5)	1.8 (1.1 - 3.0)	27 (18.1 - 42.9)	1.5 (1.0 - 2.4)	59 (34.9 - 98.6)	1.6 (0.9 - 2.6)	1.2 (0.6-2.0)
Suffocation/threats to breathing	2 (1.8 - 3.8)	0.1 (0.09 - 0.2)	2 (1.8 - 3.8)	0.1 (0.09 - 0.2)	4 (3.7 - 7.7)	0.1 (0.09 - 0.2)	0.9 (0.1-13.4)
Fire/burns	9 (3.2 - 16.8)	1.2 (0.4 - 2.2)	5 (4.3 - 8.2)	0.4 (0.05 - 0.6)	14 (9.1 - 26.2)	0.4 (0.25 - 0.7)	1.8 (0.5-6.6)
Other	12 (2.9 - 22.7)	0.4 (0.1 - 0.6)	17 (7.2 - 17.2)	0.6 (0.2 - 1.0)	29 (5.9 - 30.0)	0.2 (0.05 - 0.3)	0.9 (0.3-2.4)
Unknown	8 (5.6 - 14.6)	0.5 (0.14 - 0.91)	6 (4.9 - 10.2)	0.8 (0.14 - 1.4)	14 (9.95 - 25.5)	0.4 (0.28 - 0.71)	1.2 (0.4-4.5)

For children 17 years and younger, there was no significant difference found between the fire/burn mortality rate of males compared to females (RR=1.2; $p = .14$); however, males (2.8 per 100,000) were at a greater risk of drowning compared to females (0.9 per 100,000)

(RR=2.9; $p < .0001$). Homicide deaths (41%) contributed the most to premature mortality (YLL) for children 17 years and younger of age followed by other unintentional injury (32 %), with suicidal deaths at 1% (Figure 4.5).

Figure 4.5

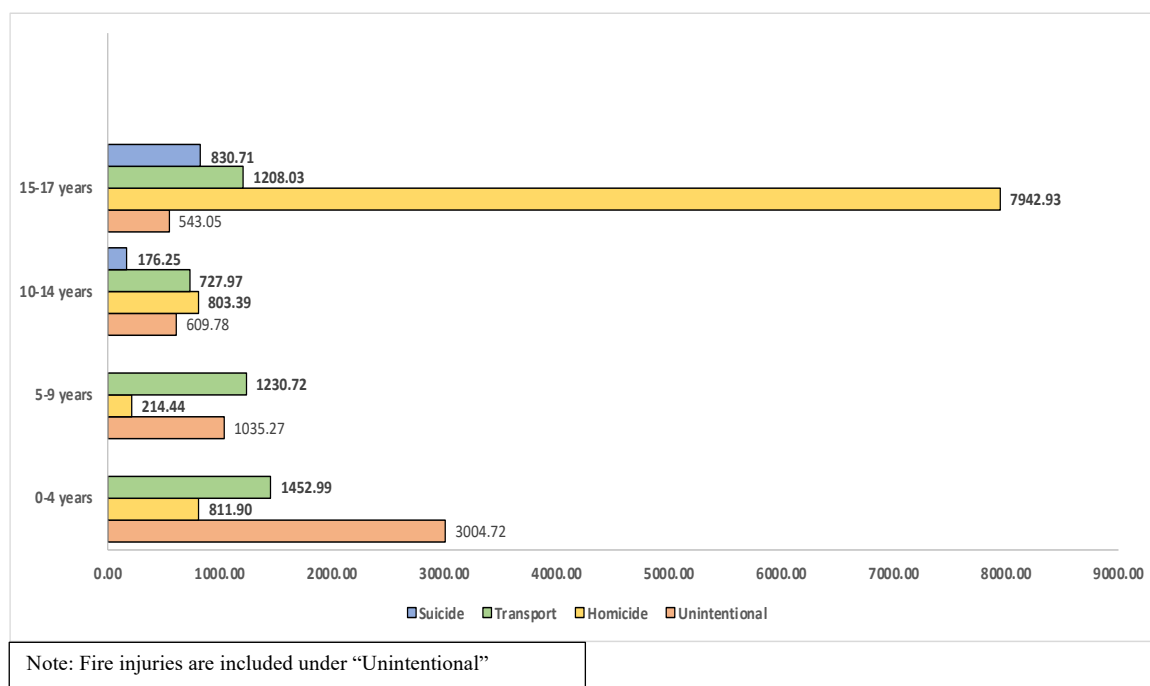
Total premature mortality (YLL) percentage (%) for leading manner of death by external cause of injury for children; 2011-2015, Metro West, CoCT



The homicide premature mortality rate was lowest for children aged 5 to 9 years (214.44), followed by children aged 10 to 14 years (803.39) and children younger than 5 years (811.90). It peaked in children aged 15 to 17 years (7942.93 per 100 000 children) from 2011 to 2015 (Figure 4.6).

Figure 4.6

Average years of life lost (YLL) per 100 000 population for apparent manner of death across age groups; 2011-2015; Metro West, CoCT



From 2011 to 2015, the homicide premature mortality rate pattern for children aged 15 to 17 years differed depending on the external cause of injury, with sharp force, which peaked in 2013 (1,079.6 YLL per 100, 000), being the leading external cause over time compared to firearm injuries (Figure 4.7). Firearm injury was the second largest contributor to premature mortality rate in this age group. There was a steady increase starting from 189.6 YLL per 100 000 children aged 15 to 17 years in 2011 and peaking in 2015 (767.4 YLL per 100 000). In 2014 the contribution of sharp force (699.5 YLL per 100 000) and firearm injury (667.4 YLL per 100 000) to the premature mortality rate for 15 to 17-year-olds were similar. The unintentional injury premature mortality rate demonstrated an inverse shape compared to homicides; with 15 to 17-year-olds having the lowest rate and peaking in children younger than 5 years over the five year period.

Figure 4.7

Years of life lost (YLL) per 100 000 15-17 year population for leading external cause of injury for homicides, 2011-2015; Metro West, CoCT

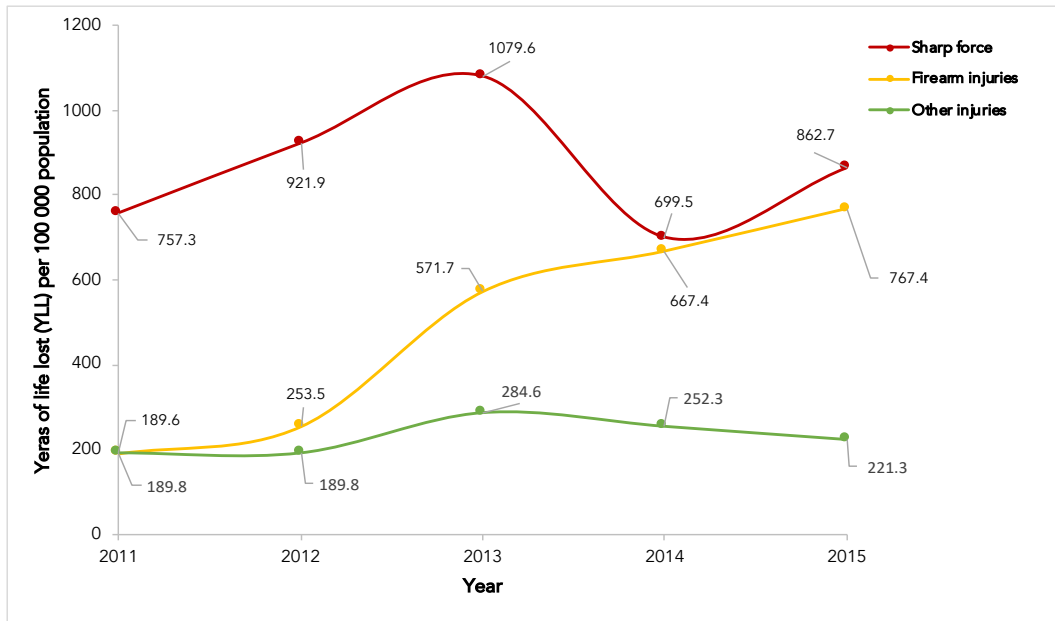
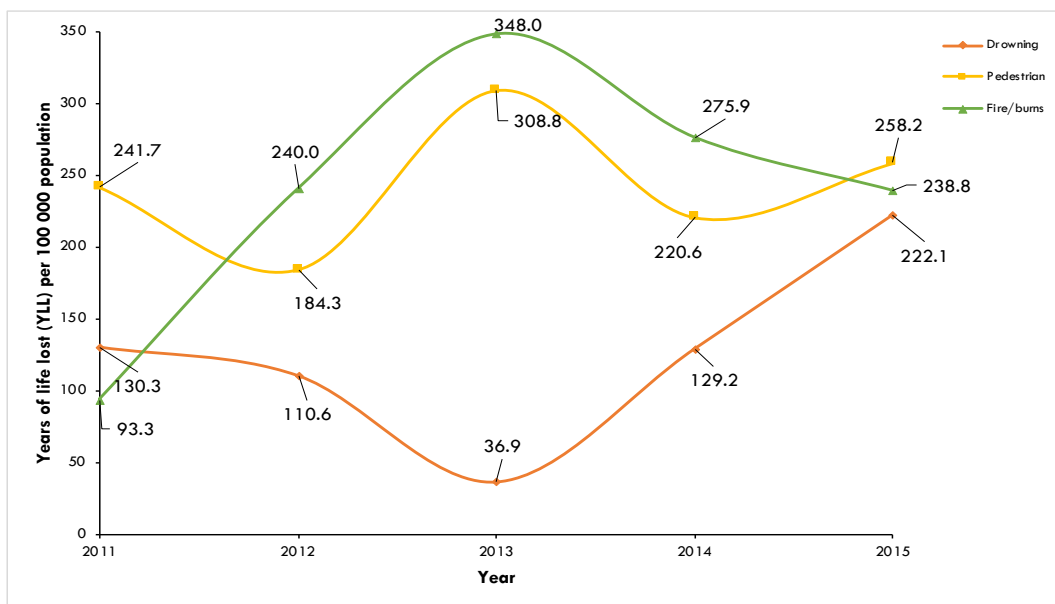


Figure 4.8

Years of life lost (YLL) rate per 100 000 under 5 population for leading unintentional external cause of injury; 2011-2015; Metro West, CoCT



For children younger than 5 years, there was a rapid increase in fire/burn-related deaths from 2011 to 2013 (Figure 4.8). The highest contributors to premature mortality over time in children younger than 5 years were fire (348.0 YLL per 100 000) and pedestrian (308.8 YLL per 100 000) injuries, with both peaking in 2013.

The study found that most child injury deaths occurred in the Klipfontein sub-health district, with a mortality rate of 280.4 per 100,000 population (Table 4.2). The lowest injury deaths were reported in the Mitchells Plain sub-health district with a mortality rate of 90.8 per 100,000 population

Table 4.2

Average annual child injury mortality by sub-health district and suburb relative to apparent manner of death, 2011-2015; Metro West, CoCT

Sub-health Districts	Apparent Manner of Death												
	Total		Homicide		Transport		Other Unintentional injury		Suicide		Undetermined		Missing
	n	Mortality Rate (per 100,000 children)	n	Mortality Rate (per 100,000 children)	n	Mortality Rate (per 100,000 children)	n	Mortality Rate (per 100,000 children)	n	Mortality Rate (per 100,000 children)	n	Mortality Rate (per 100,000 children)	
Klipfontein	332	280.5	165	139.4	67	56.6	67	56.6	12	10.1	21	17.7	1
Mitchells Plain	158	90.8	65	37.3	35	20.1	46	26.4	5	2.9	7	4	7
Southern	229	165.8	48	34.7	44	25.2	108	78.2	8	5.8	20	14.5	1
Western	189	153.1	74	60	50	40.5	44	35.7	10	8.1	11	8.9	0

Table 4.3 represents child injury deaths in each of the four sub-health districts relative to apparent manner of death over a 5 year period (2011 to 2015). For children aged 0 to 17 years, Klipfontein had the highest homicide mortality rate (139.4 per 100,000) whereas Western had the lowest (60 per 100,000). Klipfontein also reported the highest transport-related injury mortality rate (56.6 per 100,000) and highest suicide mortality rate (10.1 per 100,000) across age groups. This thesis found that the mortality rate in each sub-health district over time was relatively stable except for the Southern sub-health district, which displayed a 22 % change in mortality rate (28 per 100, 000 children aged 0 to 17 years) from 2014 to 2015 (Table 4.3). Mitchells Plain sub-health district had the lowest mortality rate over time compared to all the other sub-health districts, with the mortality rate lowest in 2011 (12.9 per 100,000 children aged 0 to 17 years) and peaking in 2013 (15.8 per 100,000 children aged 0 to 17 years). Homicides were the leading COD overtime compared to all other forms of injury and remained relatively stable from 2012 to 2015. Pedestrian deaths were the second leading COD overtime and peaked in 2014 (5.1 per 100,000 children aged 0 to 17 years), followed by fire injuries (Table 4.3).

Table 4.3

Child injury mortality (per 100, 000 population) over time (2011-2015) by age group, gender, sub-health district, manner of death, and external cause, 2011-2015; Metro West, CoCT

		2011		2012		2013		2014		2015	
		n	Mortality rate per 100,000 population	n	Mortality rate per 100,000 population	n	Mortality rate per 100,000 population	n	Mortality rate per 100,000 population	n	Mortality rate per 100,000 population
Age Category	0-4 years	60	37.1	62	37.8	63	38.3	67	40.8	83	50.7
	5-9 years	26	17.5	25	16.7	28	18.4	30	19.4	27	17.1
	10-14 years	24	15.9	19	12.7	22	14.9	31	21.9	29	19.9
	15-17 years	55	61	62	69.1	75	83.6	71	79.2	77	86.4
Gender	Female	38	10.8	47	13.3	54	15.3	61	17.2	60	17
	Male	122	33.7	119	32.7	132	36.1	136	37.2	155	42.3
	Missing	6	0.8	2	0.3	2	0.3	2	0.3	1	0.1
Sub-Health Districts	Klipfontein	60	38.8	60	44	68	44.6	71	47	73	48.8
	Mitchells Plain	29	12.9	29	14.5	36	15.8	32	14	32	14
	Southern	41	23.3	36	22.8	40	22.8	49	28	63	36.1
	Western	30	19.1	36	25.6	37	22.8	41	24.9	42	25.1
Apparent Manner of Death Leading External Causes of Mortality	Homicide	54	7.6	66	10.4	79	11	74	10.3	80	11.1
	Sharp force/Stabbing	31	4.3	38	6	37	5.2	25	3.5	34	4.7
	Transport	45	6.3	39	6.1	41	5.7	53	7.4	45	6.2
	Road traffic pedestrian injuries	33	4.6	26	4.1	32	4.5	37	5.1	31	4.3
	Other Unintentional Injuries	52	7.3	46	7.2	52	7.2	56	7.8	59	8.2
	Fire/Burns	19	2.7	19	3	29	4	24	3.3	16	2.2
	Suicide	8	1.1	6	0.9	10	1.4	3	0.4	8	1.1
	Hanging	2	0.3	4	0.6	5	0.7	1	0.1	4	0.6
	Undetermined	7	1	11	1.7	6	0.8	13	1.8	22	3.1
	Fire/Burns	1	0.1	7	1.1	1	0.1	0	0	5	0.7
	Missing	1	0.1	0	0	0	0	0	0	0	0

Table 4.4

Child injury mortality (per 100, 000 population) by age group, and sub-health district, 2011-2015; Metro West, CoCT

Sub-health Districts	Total			0-4 years			5-9 years			10-14 years			15-17 years		
	n	Mortality Rate (per 100,000 children)	Percent (95% CI)	n	Mortality Rate (per 100,000 children)	Percent (95% CI)	n	Mortality Rate (per 100,000 children)	Percent (95% CI)	n	Mortality Rate (per 100,000 children)	Percent (95% CI)	n	Mortality Rate (per 100,000 children)	Percent (95% CI)
Klipfontein	332	280.4	35.5 (32.4-38.6)	104	305.5	31.2 (26.2-36.2)	35	109	25.7 (18.2-33.1)	33	101.6	28.0 (20.0-35.9)	158	800.3	46.6 (41.2-51.9)
Mitchells Plain	158	90.76	16.9 (14.5-19.3)	44	82.4	13.2 (9.5-16.8)	25	51.3	18.3 (11.8-24.9)	26	57.7	20.8 (13.5-28.0)	63	442.6	18.7 (14.4-22.7)
Southern	229	165.78	24.5 (21.8-27.2)	118	314.9	35.4 (30.2-40.6)	41	109.7	30.1 (22.3-37.9)	31	79.2	24.8 (17.1-32.4)	38	101.4	11.2 (7.8-14.6)
Western	190	154	20.3 (17.7-22.9)	55	141.8	16.5 (12.5-20.5)	28	81.7	20.5 (13.7-27.4)	29	92.3	23.2 (15.5-30.7)	78	412.5	23.0 (18.5-27.5)

NOTE:
Missing data - Parow (n=1) | Bonteheuwel (n=2) | Khayelitsha (n=3) | Philadelpha (n=2) | Harare (n=1) | Delft (n=2) | Saldhana (n=1) | Vredenberg (n=1) | Beaufort West (n=2) | Kleinvlei (n=1) | IMfuleni (n=3) | Blue Downs (n=1) | Worcester (n=1)

Children younger than 5 years and those aged 5 to 9 years contributed to the greatest proportion of injury deaths reported in the Southern sub-health district, whereas most children aged 15 to 17 years died in the Klipfontein sub-health district (Table 4.4)*.

*Percent of injury reported by each sub-health district is determined as a proportion of total injuries and by each age

Figure 4.9

(1) Point injury map & (2) Heat Map representing the density of injury cases, 2011-2015; Metro West, CoCT

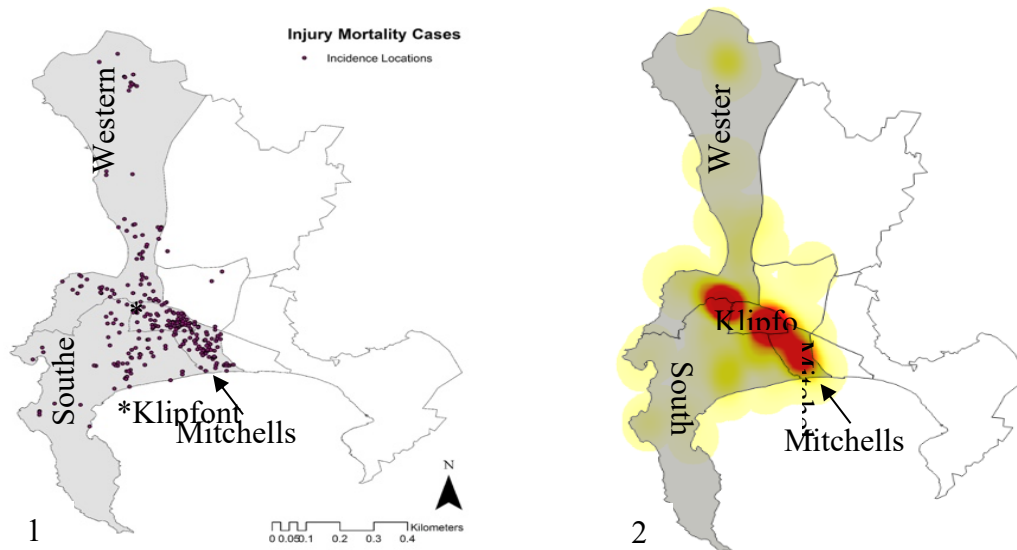


Figure 4.9 represents a visual distribution of injury deaths and a heat map representing the density of injury deaths across Metro West in the CoCT for children 17 years and younger from 2011 to 2015.

Klipfontein sub-health district has the highest concentration of both injury cases and child injury deaths. The injury mortality heat map shows that the highest density (red) of injuries per 5 km radius was mainly located within Mitchells Plain and Klipfontein sub-health districts.

The overall average injury mortality rate for children aged 17 years and younger from 2011 to 2015 differs by sub-health district and age-group (Figure 4.10 to Figure 4.12). At 4,171.8 km², the Klipfontein sub-health district has the smallest area, () and from 2011 to 2015 for children aged 17 years and younger, had the highest overall average injury mortality rate (43.7 per 100,000). By comparison, the Western sub-health district which has the largest area (64,015.8 km²) had an injury mortality rate of 24.3 per 100,000 children aged 0 to 17 years over the same period. The highest injury mortality rate for children aged 0 to 4 years, 5 to 9 years, and 15 to

17 years was in the Western sub-health district while the lowest was in the Mitchells Plain sub-health district.

Figure 4.10

Maps representing average injury mortality rate (per 100,000 population) for children aged 0-17 years, 2011-2015; Metro West, CoCT

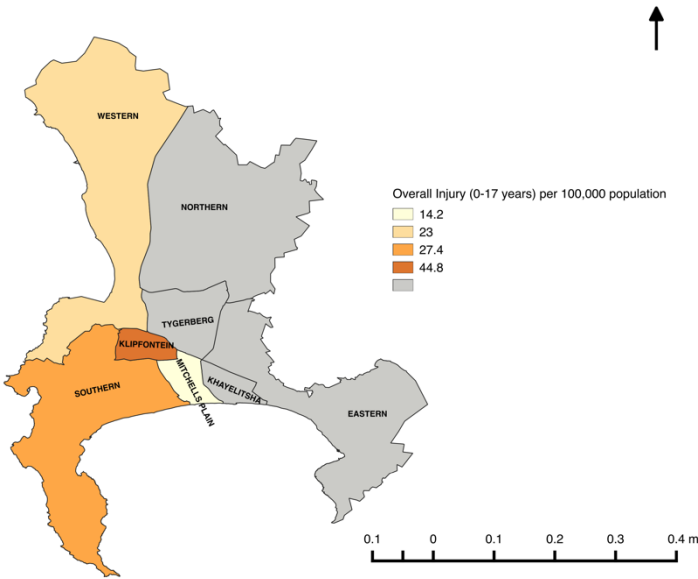


Figure 4.11

Maps representing average injury mortality rate (per 100,000 population) by age group (A: 0-4 years; B: 5-9 years), 2011-2015; Metro West, CoCT

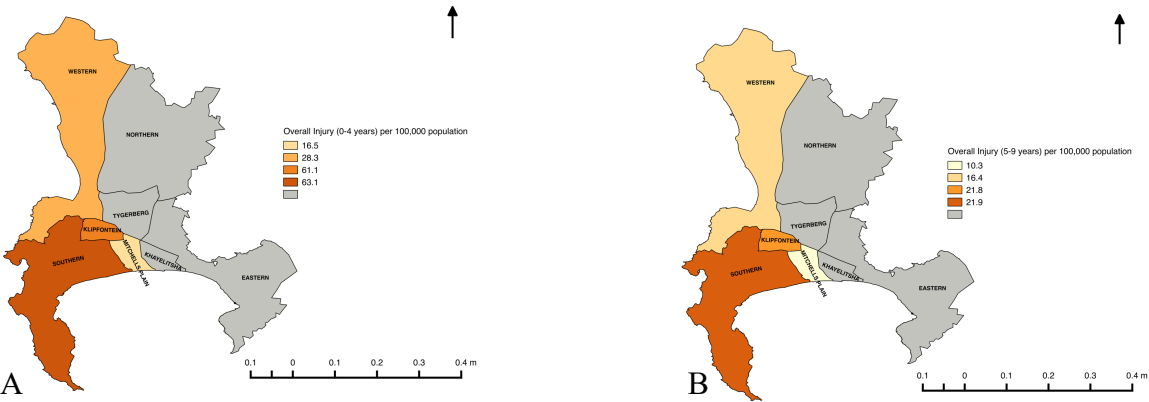
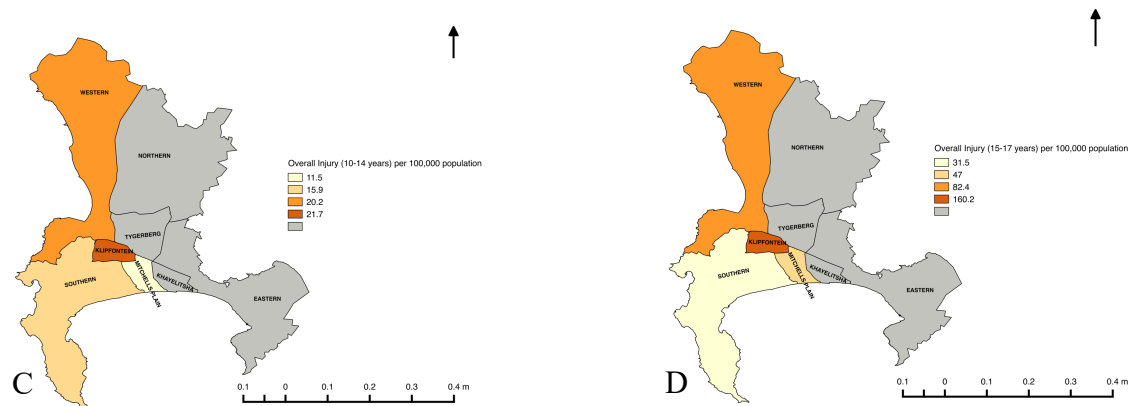


Figure 4.12

Maps representing average injury mortality rate (per 100,000 population) by age group (C: 10-14 years; D: 15-17 years) , 2011-2015; Metro West, CoCT



At 27.2 deaths per 100,000 children aged 0 to 17 years, homicide was a leading cause of death (n=353) in the Klipfontein sub-health district , with children aged 0 to 4 years, 10 to 14 years, and 15 to 17 years most impacted (Figure 4.13 to Figure 4.15).

Figure 4.13

Map representing average homicide mortality rate (per 100,000 population) for children aged 0-17 years, 2011-2015; Metro West, CoCT

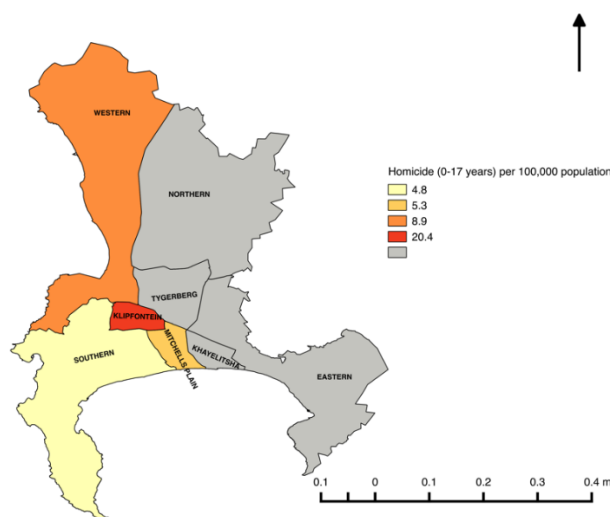


Figure 4.14

Maps representing average homicide mortality rate (per 100,000 population) by age group (A: 0-4 years; B: 5-9 years) 2011-2015; Metro West, CoCT

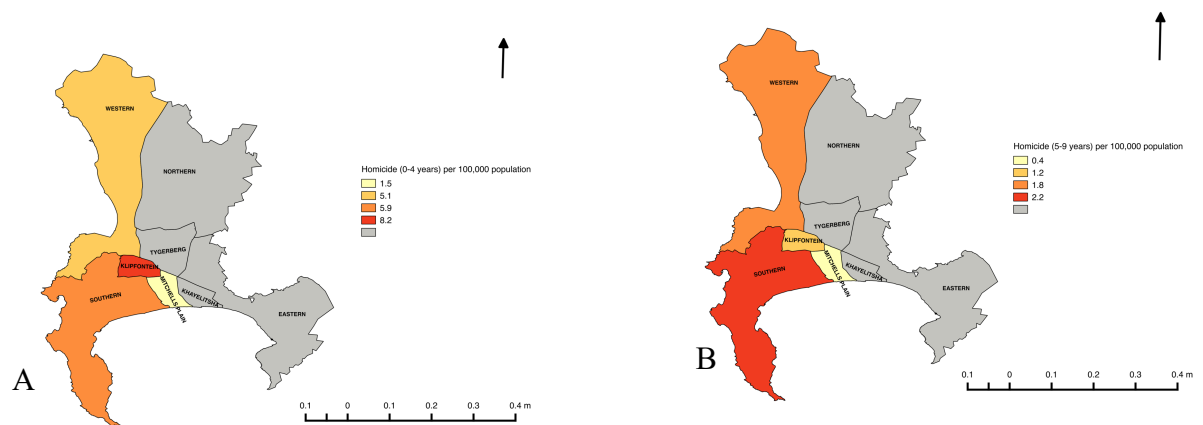
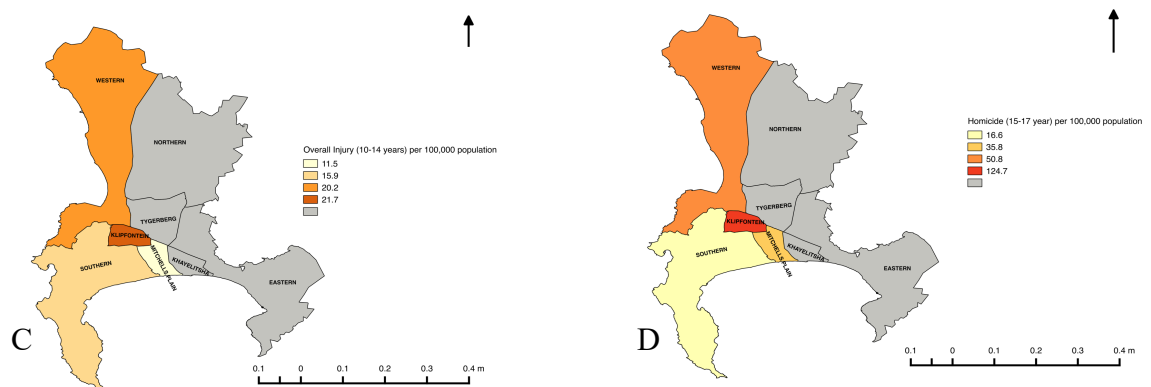


Figure 4.15

Maps representing average homicide mortality rate (per 100,000 population) by age group (C: 10-14 years; D: 15-17 years) 2011-2015; Metro West, CoCT



Pedestrian deaths were the second leading injury burden for all children, with the Klipfontein sub-health district most affected (19.9 deaths per 100,000). The most affected age groups were 0 to 4 years, 5 to 9 years, and 10 to 14 years (Figure 4.16 to Figure 4.18).

Figure 4.16

Map representing average pedestrian mortality rate (per 100,000 population) for children aged 0-17 years, 2011-2015; Metro West, CoCT

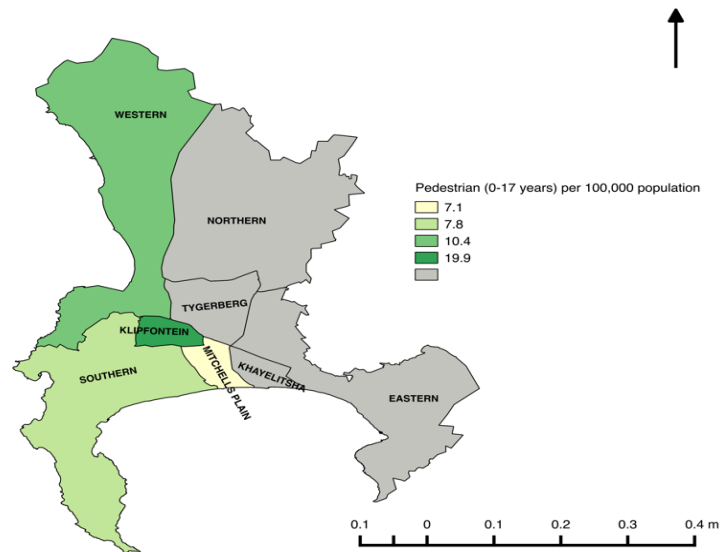


Figure 4.17

Map representing average pedestrian mortality rate (per 100,000 population) by age group (A: 0-4 years; B: 5-9 years) for children aged 0-17 years, 2011-2015; Metro West, CoCT

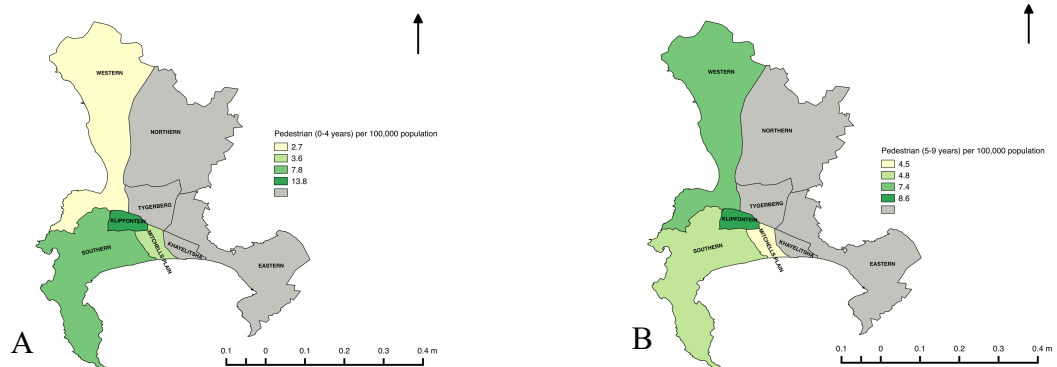
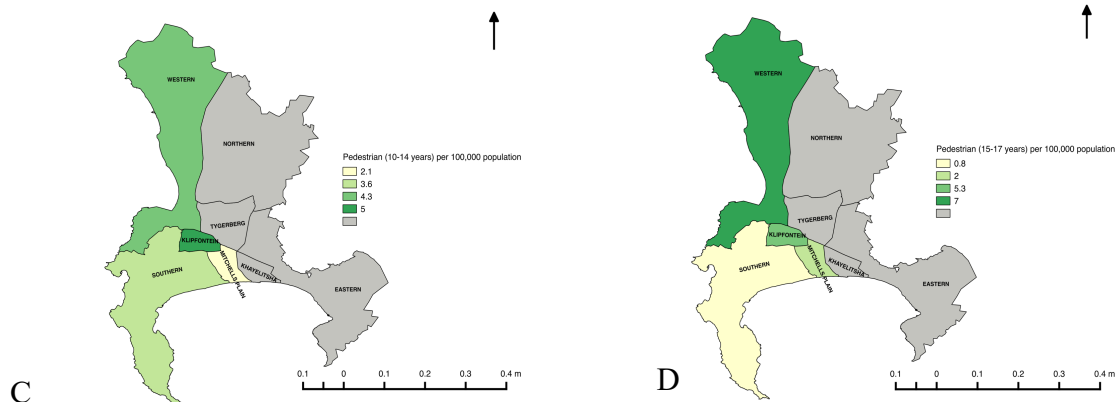


Figure 4.18

Map representing average pedestrian mortality rate (per 100,000 population) by age group (C: 10-14 years; D: 15-17 years) for children aged 0-17 years, 2011-2015; Metro West, CoCT



4.6 Discussion

This thesis found that 52.1% of children died of an unintentional injury, a significant difference from deaths as a result of intentional injuries and undetermined injuries ($p < 0.000001$). This finding is similar to both the global injury pattern for children reported in 2019 as well as the UMICs pattern (Institute for Health Metrics and Evaluation, 2021). National estimates using mortuary data for 2017 in South Africa also found that unintentional injuries such as RTCs contributed more to the injury burden than intentional injuries (Prinsloo et al., 2021). This thesis reported similar trends to national estimates of childhood injury patterns. However, the intent and manner of death differs by age group, with most children 15 years and younger dying of an unintentional injury, while those older than 15 years mostly impacted by intentional deaths

This thesis found that children aged 15 to 17 years had the highest injury mortality rate compared to any other age group. However, UMICs have reported that with a mortality rate of 12.8 cases per 100,000, children aged 15 years and older have the highest injury mortality rate compared to children aged 5 to 9 years or 10 to 14 years (Institute for Health Metrics and Evaluation, 2021). According to the second national burden of disease study in South Africa, injury mortality was highest in 2012 for adolescents aged 15 to 19 years (Pillay-van Wyk et al., 2016). Similarly, in the Western Cape injury mortality for children was highest in those aged 15 years and older (Evans J, 2018).

In this thesis, unintentional injury was the leading cause of death among children. However, homicide deaths accounted for highest injury mortality of an individual COD, specifically

sharp force followed by RTC. Homicide was also found to be the greatest contributor of premature mortality (YLL) among children particularly those aged 15 to 17 years in the Klipfontein sub-health district. This finding differs from global homicides among adolescents, UMICs, and LMICs (Institute for Health Metrics and Evaluation, 2021); as well as nationally in South Africa (Prinsloo et al., 2021 2015) as the age group reported is 15 to 19 years old.

The evidence suggests that the pattern of injury depends on where a child dies. In this thesis, most injury deaths were reported in the Klipfontein sub-health district, with homicides the most prevalent. Klipfontein is reported as having the highest concentration of informal housing with a population of approximately 380,000 individuals who have limited safe spaces from attacks (Smit, 2020). Compared to formal areas, most informal areas are unsafe, leading to greater possibility for injury death.

4.6.1 Homicide

Homicide was the leading MOD in this thesis and was found to be approximately five times higher than the national homicide rate of children aged 0 to 14 years reported in 2017 (Prinsloo et al., 2021). Age also plays a role in determining the pattern of homicide injury. In this thesis, the children most affected by homicide were adolescents and those younger than 5 years. Homicide varies depending on the child's age, with child abuse deaths more likely among children younger than 5 years and interpersonal violence driving adolescent male on male homicide (King et al., 2006).

The most affected sub-health district by homicide in this thesis was Klipfontein, which forms part of the Cape Flats, one of the most deprived areas in Cape Town with a high rate of violent crime. This thesis found that most homicide deaths are as a result of stabbing rather than being shot by a gun, which suggests that the role of interpersonal violence is a driver of the homicide burden reported in this thesis. This suggests that in these areas, stabbing is a gendered norm and a common means to resolve conflict among young men. Seedat and colleagues found that in 2004, approximately 33 % of children from high schools in Cape Town had witnessed a family member being injured, beaten, or killed (Seedat et al., 2004). Children's exposure to violence is a major contributor to violent behaviour that can normalise violence later in life (Makanga et al., 2017). Many youths living in the Cape Flats are exposed to gangs either as part of their family circle or as members of the community. The presence of gangs within this

community is normalised with many perceiving belonging to a gang as a “rite of passage” (Bility, 1999). Members of the community including youth perceive gangs to be dangerous and violent but something that they must adapt to as part of their everyday life (Bility, 1999). Since the apartheid era, gang violence has been a major problem in the Cape Flats, where the youth, often drawn to gangs, employ violent tactics in order to achieve specific goals, such as social status and power within the community (Bility, 1999). Young people in the Cape Flats are easily lured to join a gang especially a ‘super gang’, such as the Americans, through money, drugs and girls; only to be used in drug and turf wars where there is a high likelihood of dying (Swingler S, 2014).

The Western Cape Burden of Disease project (Myers et al., 2007) found several risk factors that play a dominant role in the likelihood of children being involved in a violent crime as a victim, this includes:

- Age and gender of the child
- The early onset of aggressive and disruptive behaviours
- Alcohol and substance abuse
- Societal factors such as single parent households, harsh physical punishment, and, violent neighbourhoods
- Population density and mobility
- Witnessing violence
- Visibility of gangs, weapons, and drugs
- Endorsement of violence to solve conflict
- Effectiveness of political structures
- Low educational attainment
- Inadequate housing and infrastructure

The leading external COD for homicides in this thesis was stabbing (sharp force) and firearm injuries. Stabbing was the leading contributor to premature mortality in homicide deaths for children aged 15 to 17 years and peaked in 2013 (1,079.6 YLL per 100, 000). A similar pattern was observed nationally, with the majority of child homicides as a result of stabbing (26.3 %), with children aged 15 to 17-year accounting for 78.5 % of these deaths (Mathews et al., 2019). The high incidence in stabbing can be attributed to the ease of access to sharp objects compared to guns.

Furthermore, this thesis found that from 2014 to 2015, firearm injuries contributed nearly the same to premature mortality as stabbings. The rise in firearm-related deaths could be as a result of an increase in firearm circulation levels across South Africa, despite the Firearms Control Act that was enacted in 2004 and contributed to a decrease in unintentional non-fatal firearm injuries in children treated at Red Cross War Memorial Hospital from 2001-2011 (Campbell et al., 2013). This suggests that there is lack of gun control resulting in easy access of illegal firearms in the city which has likely led to an increase in gang wars (Obioha, 2013). A known circulation of illegal guns in the CoCT started in 2007, where these weapons were moved from police custody by corrupt officials to gangs in coloured communities (Matzopoulos et al., 2018). Evidence suggests that police detectives sold nearly 2000 weapons and ammunition to gangsters from the Cape Flats from 2007 to 2015 (Matzopoulos et al., 2018). Since 2013, there have been several media reports about the rise in gang wars between rival gangs. This rise in firearm availability within the areas operated by gangs suggests that these gang wars escalated due to the supply of firearms (Matzopoulos et al., 2018). A police ballistics report found that more than 1,000 homicides and other crimes in the CoCT from 2010 to 2016 came directly from these firearms, of which 261 victims were children (Matzopoulos et al., 2018).

4.6.2 Pedestrian

In this thesis, pedestrian deaths were the leading external COD for children younger than 15 years alongside sharp force injuries across all age groups. This followed a similar YLL injury rate as fire injuries from 2011 to 2015, peaking in 2013 (308.3 YLL per 100,000population). The average pedestrian mortality rate in this thesis across all ages was 4.4, which was 3.4 times lower than the national average in 2009 for children younger than 14 years, which represents the latest national injury mortality rate (Matzopoulos et al., 2015). National injury data for children is not usually disaggregated through a child lens that would inform interventions across the developmental spectrum. Like most injury deaths, this thesis found that males were more vulnerable than females as pedestrians. Evidence suggests that males are more at risk of dying as pedestrians than females due to their inherent risk-taking behaviour such as running into oncoming traffic or playing on the road (Harré, 2000 2008). Lack of supervision, especially among young children, and traffic calming interventions, such as traffic circles, impacts the risk of pedestrians (Waylen & McKenna, 2008). To improve pedestrian safety, exposure to risk needs to be reduced. This can be achieved by enforcing speed limits, especially in suburban areas, where children are likely to play close to the road; improving safety

infrastructure; and the availability of effective and appropriate alternative modes of transport for vulnerable road users such as children (Peden et al., 2004).

4.6.3 Fire Injury

Fire injury was the third leading external COD across all age groups, with the greatest impact in children younger than 5 years from 2011 to 2015. Majority of these fire injuries occurred in 2013 and were responsible for nearly 348.0 YLL per 100,000 children younger than 5 years. Over the past decade, the CoCT has seen a rapid increase in shack fires due to dry windy conditions causing an increase in runaway fires (Walls & Zweig, 2017). A rise in the number of dwellings in informal settlements comes with more open flame cooking, and illegal electrical connections, further contributing to the incidence of fire injuries (Walls & Zweig, 2017). This suggests that these deaths, especially in children, are directly linked to the unsafe housing environment of impoverished areas in the city that lack brick houses and suitable fire-resistant infrastructure. South Africa has one of the largest subsidised housing programmes in the world (Brown-Luthango et al., 2017). To protect children in terms of the constitution, it is the state's obligation to provide shelter independent of and in addition to the obligation to take reasonable legislative and other measures. Additionally, the state is tasked with providing rudimentary shelter to children irrespective of resource availability (art. 28(1)(c)) (Caron et al., 2003). However, the question remains, if parents are unable to fulfil the rights of their children due to poverty and children are subjected to unsafe living conditions; where does the responsibility lie to protect the rights of these children?

According to the 11th Sustainable Development Goal ([SDG](#)) which aims to ensure cities and human settlements are inclusive, safe, resilient, and sustainable, it is expected that nearly two-thirds of the population will be living in urban areas by 2050. It is therefore imperative that all human settlements are provided with adequate shelter; access to environmental structures such as clean water, sanitation, drainage and solid waste management; and ensure sustainable land use and planning. With these measures in place, all children will reside in homes that are less likely to burn down and are less likely to cook with unregulated highly flammable products, thus reducing fire-related injuries.

4.6.4 Geographic Area and Injury Mortality

This thesis found that the Klipfontein sub-health district, which has the lowest SES (STATSSA, 2011) (specifically high unemployment rate and low household income), had the densest injury cluster. Nyanga, in Klipfontein sub-health district, is one of the most impoverished suburbs in the CoCT (Crimestats, 2021; South African Police Services, 2020). , In 2021, it was reported to have one of the highest homicide rates over the past 5 years, with 58 homicide deaths per 100, 000 across all ages (Crimestats, 2021; South African Police Services, 2020). This thesis focussed on child homicides since the data reported by SAPS and CrimeStats reported homicides across all ages, which masked child homicides in these datasets and failed to provide a clear burden of child homicide in the CoCT. This evidence suggests that child homicides (0 to 17 years) may not be occurring in the neighbourhood reporting the highest homicide rate in the city. However, similar to this thesis, Groenewald and colleagues found homicides increased with age, where the most at risk were children older than 10 years (Groenewald et al., 2017). This thesis found that in Klipfontein, children aged 15 to 17 years had the highest overall injury mortality rate and the highest average homicide mortality rate for all children except for those aged 5 to 9 years. Klipfontein has the lowest population of children compared to the other three sub-health districts but had the highest injury mortality rate in this thesis. There are limited studies highlighting child injury mortality density within populations and the suburbs most at risk. However, according to Cusimano et al. (2010), the densest injury clusters are in the most deprived areas

Many studies have suggested urban upgrading as one way to improve safety measures in violent communities. However, after Mitchells Plain, Khayelitsha and Phillippi had initiated violence prevention through urban upgrading programmes, many of the residents felt that crime had increased and their living conditions not improved (Brown-Luthango et al., 2017).

The Southern sub-health district had the second highest injury mortality rate across all age groups; however, children aged 10-14 years represented the lowest overall injury mortality rate. This sub-health district also had the lowest overall homicide mortality rates for children aged 15-17 years and the second lowest pedestrian mortality rate for all children except those younger than 5-years and 15 to 17 years. has Many of the wealthy suburbs such as Camps Bay, Bishops Court, and Constantia are found in this sub-health district, with only a few informal settlements such as Red Hill, Capricorn, and Imizamo Yethu located in the greater

Hout Bay Valley area. These informal settlements have a higher number of injury deaths compared to the wealthier areas mentioned above. In recent years, Imizamo Yethu has experienced countless fire outbreaks, such as the March 2017 fire, which left nearly 15,000 people homeless (Hyman A, 2018).

This thesis found that the Western sub-health district had the second highest overall pedestrian mortality rate, with children younger than five years having the lowest rate. Interestingly, there are many active RTC preventative initiatives in place within this sub-health district, such as Chevron Visibility Program, a pedestrian road safety program in Du Noon that aims to make children (5 to 14 years) more visible to drivers by wearing reflective clothing. However, despite the highest pedestrian mortality rate reported in this sub-health district being those aged 15 to 17 years, road safety interventions are not targeted for this age group. Although the highest pedestrian mortality rate was in the Klipfontein sub-health district in children younger than 15 years, there is a lack of pedestrian safety interventions in place.

Published child injury mortality data is limited, with most national injury mortality data not child focused. In South Africa, there is a major gap in the publishing of child injury mortality at the nationwide level. There is a 9 year gap between this thesis and the last release of child injury mortality data, which is a detriment to prioritising the injury burden in South Africa. Therefore, compared to the IMS, this thesis provides insight into the child injury mortality burden by smaller area location, and the need for more research in this area of study.

4.6.5 Policies and Legislation

To reduce and manage the child injury burden, targeted initiatives and programmes need to be prioritised. In 2011, the World Health Assembly urged member states to prioritise child injury prevention at the national level (World Health Organisation, 2013). In South Africa, child injuries have not been included in the national health priority list (Van As & Dhali, 2017), despite the WHO's findings of a global and regional rise in child injury incidence (Institute for Health Metrics and Evaluation, 2021). Injury surveillance is needed to monitor change in injury trends (Pressley et al., 2007), with a need to routinely identify socio-economic groups along with vital statistics. Additionally, injury prevention interventions for each cause-specific death need to be age appropriate.

4.6.6 What Should Be Done: Recommendations

Based on the evidence from this thesis, a nationally representative reliable injury surveillance system that utilises routine data is recommended. Initiatives that prevent child injury mortality, especially for homicide and pedestrian deaths, need to be more child centred to ensure their effectiveness and appropriateness. These initiatives need to be developed and implemented by multidisciplinary teams comprising of criminal justice, health, urban development, and the environment in collaboration with NGOs and academics.

Furthermore, the initiatives should target areas most at risk, with surveillance systems that include hotspots of where injuries are most likely to occur based on the age of the child. These initiatives should be well monitored and documented, targeted at primary prevention, and be long-term enabled. The initiatives should also target social norms and behaviours that lead to violence and aggressive behaviour, by targeting inequities driven by a culture of intolerance and the disrespect of basic human rights. Additionally, to ensure accountability and sustainability, these initiatives should be implemented and institutionalised at both the municipal and provincial level.

Violence prevention programmes, through urban upgrading, have shown a positive effect in the prevention of violence and crime globally (Cassidy et al., 2014), specifically in HICs. A study by According to Brown-Luthango et al. (2017), upgrading of neighbourhood-level townships in the CoCT is dependent on the physical location of the initiative, resulting in a modest reduction in violence activities. These areas, characterised by high unemployment and poverty levels, include Freedom Park, Mitchells Plain; Sheffield Road, Philippi and Monwabisi Park, Khayelitsha. The researchers found that due to a lack of programmes targeting structural factors, such as population density, which drive and sustain high levels of violence, the change in violence activity would not be sustained long-term (Brown-Luthango et al., 2017). However, an initiative by the Violence Prevention through Urban Upgrading (VPUU) in Harare informal settlement (Khayelitsha), called the VPUU business development upgrading, found a decline in robberies (Krause & Shay, 2016). The success of this initiative can be based on the collaboration between the local community and stakeholders such as VPUU. Together, they can prioritise the development and implementation of community action plans relative to the socio-political setting and budget of the area (South African Cities Network, 2011).

To prevent further pedestrian death, it is recommended that speed limits are enforced, traffic calming measures are in place, and targeted interventions based on the developmental age of children most at risk is developed and implemented. A more in depth discussion of the RTC burden and potential recommendations will be provided in Chapter 6 discusses the.

This thesis reported that most burn-related deaths were experienced by young children, especially those living in deprived areas. Such areas generally do not have safe measures to cook food, keep warm, or provide light in the home. Homes in these areas generally rely on firewood, paraffin or candlelight for cooking meals and providing warmth and light. As a result, young children are at high risk of fire-related injuries because it is difficult to safely contain wood fire and paraffin. Burn prevention initiatives should aim at protecting children from getting burnt when food is being cooked and the house is being heated, or lit using wood fire and paraffin. Childsafe in collaboration with Woolworths South Africa have two programmes namely the Safer Candle Project and Kettle Strap Project, which aim to empower carers with the knowledge to prevent burn injuries (Childsafe, 2018). Falling candles are one of the leading causes of shack (informal home) fires that result in severe injury or death of people, especially children, residing in the shack (Cervantes et al., 2019). The Safer Candle Project teaches carers that if a lit candle is placed inside a glass jar and is accidentally tipped over, it would knock out the flame and prevent the shack from catching fire (Childsafe, 2018). A cost-effective strap that can be tied to a kettle can keep the cord safely tucked away from tiny hands, preventing hot water burns.(Childsafe, 2018). Both interventions are cost-effective and practical in preventing burn-related injury or death especially in vulnerable and deprived areas.

4.6.7 Strengths and Limitations

Some limitations of this thesis included the data source, the scale and incident location of geographic data. The primary data source was SRM that only covers the Metro West area of the CoCT. To encapsulate the child injury burden of the city, it is essential to include data from all the sub-health districts of the CoCT. Nearly all RTC deaths occurred in a health facility and not at the RTC site, therefore details of where the crash occurred was not available; hence prioritisation to prevent these deaths based on place of incident was not possible. To assess the overall injury burden, morbidity data is needed; however, only injury mortality data was

utilised. Mapping child injury morbidity within the city can highlight the levels of access to care and type of injury.

Mortuary data was used in the study because of its quality and reliability. Geographic data from the mortuary was reliable because the incident data was collected at the time and location of the child's death.

There is an urgent need for a more sustainable and representative national injury surveillance system to be integrated with routine health information systems. The monitoring of child injury mortality in South Africa needs to be strengthened.

Majority of RTC deaths were hospital-based; therefore, it is necessary to integrate mortuary, emergency services, SAPS, and traffic-related data to determine where an accident took place relative to the death.

4.7 Conclusions

From 2011 to 2015, homicides were the leading cause of child injury death in the western geographic area, CoCT, followed by road traffic pedestrians, with males being most affected. Injury deaths by age-group has a bimodal shape, impacting both younger (under 5 years) and older children (15 to 17 years). Mapping child injury deaths highlights where the burden is the greatest as well as visually representing which cause of injury is prominent. The findings from this thesis highlight the need to prioritise child injury preventative strategies within the municipality based not only on age and injury type, but also place.

Chapter 5: Spatial Analysis of Transport-Related Child Injury Mortality City of Cape Town from 2011-2015

5.1 Background

In 2019, the global RTC mortality rate in children aged 0 to 14 years was 10 per 100, 000 which was lower than the mortality rate (15 per 100,000 children) over the same period (Institute for Health Metrics and Evaluation, 2021). Children younger than five years contributed the most to the RTC burden (5.8 per 100, 000 children) compared to any other age group ,with those residing in Africa, especially the Democratic Republic of Congo (DRC), being most affected (Institute for Health Metrics and Evaluation, 2021).

LMICs are greatly impacted by RTC deaths, contributing to 40.9 % of all global RTC deaths (Institute for Health Metrics and Evaluation, 2021). The RTC mortality rate from LMICs was 2.6 times lower than the global rate. (Institute for Health Metrics and Evaluation, 2021). Various risk factors influence this difference. Medical and structural infrastructure dominate the transport-related injury discourse, especially in RTC injuries such as pedestrian incidents, with these deaths having social, economic, political, and personal repercussions. For example, in 2015, the total cost of RTC deaths in South Africa was R142.9 billion, which accounted for 3.4% of the Gross National Product (GNP) (Labuschagne et al., 2017) compared to a range of 1 to 4.6 of the GNP in high-income countries (Wijnen & Stipdonk, 2016). These assessments do not include the mental health implications endured by the families impacted by the death of a child from an RTC injury. The complexity of RTC injury deaths is a major challenge for public health policymakers and practitioners because protection is needed for three vulnerable groups namely pedestrians, who account for 70% of transport-related deaths, passengers, and cyclists (Jacobs et al., 2000). Therefore, multiple preventative initiatives are required to prevent RTC deaths

To improve RTC injury prevention and control efforts, this thesis utilises a spatial epidemiological approach, which highlights the role of urban geographies in child RTC injury deaths through spatio-temporal analysis.

RTC injury incidence varies across neighbourhoods within cities ; for example, Bell and Schuurman (2010). highlighted RTC high-risk urban areas (hotspots) using GIS, while Rukewe et al. (2014) reported that in 2011, most pedestrian clusters were found in the Ibadan

metropolis. Additionally, a study in Thailand found that the highest pedestrian clusters were in crowded and urban areas (Bunnarong & Upala, 2018).

GIS technology and methodology is a powerful toolset used to analyse spatial data and has been useful in identifying the links between injury and the social and physical environments (Gorman et al., 2001; Walker & Schuurman, 2012). Several studies have suggested a strong correlation between RTC injury and space-time factors associated with social physical urban environments (Brubacher et al., 2016; DiMaggio & Li, 2012). These relationships are further strengthened by including a temporal variable. Soltani and Askari (2014) found that between 2011 and 2012 in Iran, most traffic accidents occurred during traffic congestion peak hours, specifically in districts with higher speed and traffic volume.

This thesis differs from Walker et al. (2014) because it is focused on children of all ages. The availability of data includes a deeper analysis of pedestrian deaths by including deprivation data at the ward level. Social structure and various socio-economic indicators and indices, such as income inequality and employment status, are strong predictors of injury risk (Kontopantelis et al., 2018).

This thesis focused on the death of a child aged 0 to 17 years as a result of transport related injury (TRI) in the Metro West, CoCT, South Africa, whether the child was a pedestrian, motor vehicle passenger or cyclist. The study investigated how these incidents clustered in space and time and examined how these patterns influence the nature of the child (demographics) and the socio-economic deprivation level of the neighbourhood where the incident took place.

5.2 Specific Objectives

This chapter aims to describe the pattern of fatal TRIs, specifically when these incidents take place. To investigate geographical clusters of fatal transport-related injuries for children aged 0 to 17 years within the four sub-health districts (Western, Southern, Klipfontein, and Mitchells Plain), CoCT, South Africa.

5.3 Specific Methods

5.3.1 Data Collection

Data was collected from the SRMs autopsy office database and entered into an excel spreadsheet. The variables analysed included the child's demographics (age and gender), location of transport-incident (i.e., death), location type (i.e., scene of death), and mechanism of injury (i.e., pedestrian or motor vehicle accident). Identifiers were unavailable. Additional data was collected to represent the neighbourhood-level environment; this includes the socio-economic deprivation level from the South African Index of Multiple Deprivation (SAIMD), average speed limit and number of lanes from SANRAL.

5.3.2 Data Analysis

5.3.2.1 Base Map and Deceased Data Analysis

Mechanism of injury was aggregated into motor vehicle crash injury; pedestrian injury; and cycle and other transport injury (i.e., cyclist collided with motor vehicle or fell off a bicycle or train) to aggregate similar mechanisms therefore there would be adequate cases in each cohort for the analysis. There were separate shapefiles created for all transport injury cohorts and for each of the mechanisms. For all transport-related incidences, age was analysed and stratified into age groups: 0 to 4 years, 5 to -9 years, 10 to 14 years, and 15 to 17 years. The data was imported into STATA v12 for statistical analysis.

Base map data layers used in the study included the four sub-health district boundaries, small area boundaries, incident coordinates, population under 18 years, and deprivation information at the ward level (Noble et al., 2013). All the maps and analysis used the Transverse Mercator LO19 World Geodetic System 1984 (WGS84) projection coordinate system.

The location of each injury death was assigned to the relevant suburb and sub-health district, with each incident assigned a unique identifier. The researcher imported this information as a CSV file into QGIS to be converted to a shape file which was used for geographical analysis.

5.3.2.2 Heat Map – Kernel Density Estimation of All Transport Deaths

A heat map was created using the Kernel Density Estimation algorithm to determine how transport-related deaths were spread across the area of interest. Where most of the transport deaths occurred, areas that were dark in colour suggested a high-density value compared to those that were light in colour. Transport deaths were mapped relative to the suburb of the

death in QGIS. A 1 km heat map search radius was used to specify the distance that each point would be highlighted i.e., more data points within the search radius would provide a greater smoothing compared to a small amount of data points.

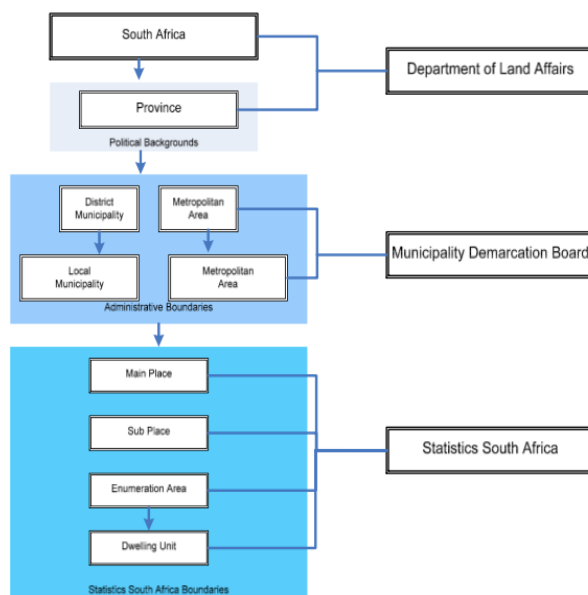
5.3.2.3 Poisson cluster analysis

The Discrete Poisson model from SaTScan was used to determine if transport-related fatalities significantly clustered in space and time over the period of interest for each sub-health district. Figure 5.1 represents the geographical hierarchy utilised in South Africa, with the highest level being nationwide and the lowest level being dwelling i.e., household level. The model used in this thesis uses population data at the sub-place level i.e., suburb (Figure 5.1).

SaTScan tests whether there is spatial autocorrelation from the null hypothesis. In this thesis, spatial autocorrelation is defined as the location of fatal transport-related cases that is dependent on the location of other transport injury locations i.e., where a transport injury death occurs increases the likelihood for other children to die due to a transport-related incident at the same location.

Figure 5.1

Geographical hierarchy, Census 2011, STATSSA



This thesis investigated how these incidents cluster in space and time, how these patterns are influenced by the demographics of the child, such as age and gender, and the South African Index of Multiple Deprivation of the neighbourhood (or main place) where the transport death occurred (Noble et al. 2013).

Neighbourhoods have the lowest geographical level of aggregation (Figure 5.1) based on available population data needed to generate sensible mortality rates for the analysis. Population data from the Census 2011 was projected for the period 2012 to 2015 for each age group under 18 years (0 to 4 years, 5 to 9 years, 10 to 14 years, and 15 to 17 years) and for each sub-health district. For the purposes of the Discrete Poisson analysis in SaTScan, centroids of the sub-health districts were used to classify the location of the population at-risk and the injury cases occurring within each sub-health district.

The null hypothesis for the Discrete Poisson model states that the expected number in each sub-health district is proportional to the population size. This analysis took temporal data into account. Based on the Poisson assumption, the likelihood function for a specific window is proportional to:

$$\left(\frac{c}{E[c]} \right)^c \left(\frac{C-c}{C-E[c]} \right)^{C-c} I()$$

Where C is the total number of transport-related fatal injury cases; c is the observed number of transport-related fatal injury cases within the window; and E [c] is the covariate adjusted expected number of transport-related fatal injury cases within the window under the null hypothesis. This analysis is conditioned on the total number of observed transport-related fatal injury cases, where C-E[c] is the expected number of transport-related fatal injury cases outside of the window; and I() is the indicator function which is equal to 1 if C > E [c] or otherwise 0. This thesis was only interested in detecting clusters with high rates; therefore I () was set to 1 (Kulldorff, 1997).

In addition, the Discrete Poisson model also determines the likelihood ratio which tests for significance of clusters using the Monte Carlo method. This likelihood function is maximised across all window locations and sizes, of which the window with the maximum likelihood is the one creating the most likely cluster i.e., the cluster least likely to occur by chance. A circular

window is centred on each sub-health district centroid and the diameter is varied from zero to one that includes a prior dependent on a certain maximum proportion of the total number of case events. The p value is determined via Monte Carlo hypothesis testing (Dwass, 1957) whereby each test statistic is calculated for each random replication and real data set; if the latter is among the highest 5%, the test is significant at 0.05 and if among the highest 1%, the test is significant at 0.01. The hypothesis test is always unbiased irrespective of the number of replications chosen for the study; the more the replications performed the higher the power. SaTScan sets the number of replications to at least 999 so that the power of the test is appropriate. Small data sets, like the one used in this thesis, had 9999 replications (Kulldorff, 1997).

The number of observed transport injury deaths in a cluster is compared to the expected transport injury deaths if the spatial and temporal location of all the transport injury cases is independent of each other so that there is no space-time interaction. Therefore, a cluster in a geographical area within a specified period is determined when the geographical area of interest has a higher proportion of its transport injury cases for that period compared to the remaining geographical areas.

For example, in a specific week, all the geographical areas have twice the number of transport injury deaths than normal, but none of these areas constitute a cluster. Alternatively, if in that week, one geographical area has twice the number of transport injury deaths compared to other geographical areas that have a normal amount of transport injury deaths; there would be a cluster in that area first.

The geographical cluster size is primarily set at a maximum of 50% of the population size in which SaTScan can evaluate clusters of any size, from very small to very large. The hotspots were determined to be locations that had a minimum of 5 incidents recorded and were ranked based on the number of transport deaths recorded over the 5-year period. The data was imported into QGIS to highlight a simple visual examination of transport injury death locations and a precise identification of all transport hotspots. Each kernel search was 1km, as it was the most appropriate distance to highlight unique incident locations.

5.3.2.4 Spatial Regression Analysis

A spatial regression analysis was performed in R to determine the relationship of fatal transport cases and various risk factors such deprivation score, gender, and age within the Southern, Western, Klipfontein, and Mitchells Plain sub-health districts from 2011 to 2015.

The spatial regression analysis used the specialised R packages in Table 5.1. The characteristics of the data should include case count, fatal rate per 100,000 population, overall deprivation score, education deprivation score, material deprivation score, employment deprivation score, living environment deprivation score, population count, and spatial features such as GPS coordinates and area in square metres for each location of interest

For this thesis, this dataset was created in ArcGis. Once the dataset had been imported, all the data types were viewed to ensure that each variable was the correct dataset To determine the relationship of fatal transport cases and various risk factors, the NB regression model adapted from (Amram et al., 2015a) was used. Using R statistical software (R Core Team, 2021), NB models were created to evaluate the relationship between deprivation score and transport-related injury rate..

Table 5.1*Specialised R packages used for spatial regression analysis*

amelia	ape	broom	car	class	classint	cleangeo	cluster
codetools	colorspace	corrplot	cowplot	crayon	dbplyr	dplyr	dtplyr
fs	future	gam	gargle	gdata	geojson	geometrics	geoR
geosphere	ggplot2	ggpubr	ggrepel	ggsci	ggsignif	globals	gmodels
glue	gmp	grid	gridExtra	gtable	gtools	here	highr
ISLR	import	ids	janitor	jqr	jquerylib	jsonify	jtools
knitr	KernSmooth	leafem	leaflet	leaflet.providers	leafsync	LearnBayes	learnr
lifecycle	lwgeom	magrittr	MapGAM	markdown	MASS	matrix	MatrixModels
nlme	numDeriv	openxlsx	OpenStreetMap	pander	pbkrtest	pkgconfig	png
polynom	prettyunits	prodlim	progress	progressr	proxy	pryr	ps
pscl	purrr	quantreg	r6	RandomFields	rappdirs	rapportools	raster
RColorBrewer	RcppArmadillo	RcppEigen	readr	readxl	recipes	rematch	rematch2
Renv	repairData	reshape2	rgdal	rgeos	rio	rjava	rlang
rmapshaper	rspectra	rstudioapi	rvest	s2	scales	selectr	sf
shiny	spam	spamm	spatial	spatialreg	spatstat	spatstat.sparse	spatstat.utils

spdep	spawr	splancs	SQAUREM	stargazer	stars	stats4	statsr
stringi	stringr	summarytools	tidyr	tidyverse	timedate	tinytex	tmap
viridis	withr	xml	xml2	wk	dev.off	mapproj	

Firstly, the correlation between both individual demographic variables and geographic variables with injury rate was examined. The second used the SAIMD composite SES variables together with the geographic variables to evaluate a similar relationship. An NB model was used because the outcome variable had a Poisson distribution that was over-dispersed (the variance does not equal the mean). NB models allow this but Poisson models do not (Gardner et al., 1995). The first model involves variable selection whereby the relationship between each individual demographic variable and transport-related injury rate (count/mean population) for children aged 0 to 17 years, was first examined. Variables resulting in a significant relationship of $p < .2$ were used as potential variables in the final model. The final model only included variables with a significant correlation of $p < .05$. The second model examined the relationship between transport-related injury rate, as the dependent variable, and the SAIMD and geographic variables, as the independent variables. The model residuals were examined to assess whether spatial dependency affected the results.

5.3.2.5 Missing Data

Missing location and time data was adjusted for in the analysis. This was done to avoid the possibility of statistically significant low rates where data was missing or statistically significant high-rate clusters in locations that were not of interest (i.e., artefacts of missing data). Missing data in this chapter was adjusted for by removing this data for every period that data was missing.

5.4 Data Sources

In addition to descriptive data for each case (COD, age category, and gender), two supporting data sources were used namely SAIMD (2011) and SANRAL (2019).

5.4.1 *South African Index of Multiple Deprivation (SAIMD) at Ward Level*

The SAIMD was developed by Noble and colleagues using data extracted from the Census 2011 to describe the multiple deprivation at the sub municipality level in South Africa. Deprivation in this context refers to individuals having unmet needs and is defined as “lacking the types of diet, clothing, housing, household facilities and fuel and environmental, educational, working and social conditions, activities, and facilities which are customary” (Townsend, 1987). The SAIMD model is a separate measure of different dimensions (or

domains) of deprivation including employment deprivation and education deprivation. These domains are measured at the household level (e.g., material deprivation domain) or the individual level (e.g., education deprivation domain), with the overall SAIMD combining each individual domain of deprivation by equal weighting (Noble et al., 2013). There were four domains of deprivation identified from the Census 2011; income and material deprivation, employment deprivation, education deprivation, and living environment deprivation (Noble et al., 2013).

Several steps were taken to develop this small area index. Firstly, the spatial scale was selected at the ward level because it has a relative population size and boundaries which do not change much over time (Noble, Wright, & Cluver, 2006). Secondly, the deprivation domains and their indicators were selected relative to the South African context; these domains were: income and material deprivation, employment deprivation, education deprivation, and living environment deprivation (Noble, Wright, & Cluver, 2006). Thirdly, each domain was a combination of indicators and created as a simple rate e.g., proportion of individuals experiencing employment deprivation. Each ward within every province was assigned a score for each domain followed by standardisation of the scores by ranking (Noble, Wright, Smith, et al., 2006). This provided an outlook of each deprivation dimension in every province. Domain deprivation measures were then combined to create a multiple deprivation measure. Finally, domains were combined to create an overall index by first standardising domain indices by ranking scores in each domain. Next, domain indices were transformed to an exponential distribution; i.e., domains were standardised at the ward level Provincial Indices of Multiple Deprivation by stretching the most deprived 25% of wards in each province due to the high levels of deprivation in South Africa. Lastly, to combine the domains, a weight was attached to each domain (Noble, Wright, Smith, et al., 2006).

This thesis utilised the SAIMD to determine which small areas located within this thesis area were most and least deprived. A heat map was created to highlight the deprivation rank of each small area. An excel spreadsheet containing the ranks for each ward in the CoCT was imported to QGIS and converted to a shapefile. The boundary shapefile was joined to the SAIMD layer to create a new layer that only included these areas. A heat map was created with the new SAIMD layer to highlight areas that were most and least deprived. The new SAIMD layer was

then added to the RTC shapefile to determine areas with high RTC death rates relative to deprivation score.

5.4.2 *South African National Roads Agency*

SANRAL is responsible for the development, maintenance, and management of South Africa's National Road network, including provisional and regional road segments. Its core values encompass four pillars namely roads, road safety, stakeholders, and mobility. The roads pillar focuses on the management of toll roads, road engineering, and maintenance of various road safety aspects, while the road safety pillar focuses on research and data collection on collisions, public awareness and road safety education, improved road incident management systems, developing engineering standards for safer roads, and strengthening partnerships for law enforcement (SANRAL, 2021). This thesis used the speed limit and number of lanes on roads in the area of interest.

5.5 Data collection

Data, which included location of death, was collected from the SRMs autopsy office database and captured in an excel spreadsheet. The location of the child's death was the same as where the accident had occurred. The variables analysed included the child's demographics such as age and gender, location of transport incident, i.e., death, location type, i.e., scene of death, and mechanism of injury, i.e. pedestrian or motor vehicle accident. Identifiers were unavailable. Additional data was collected to represent the environment at the neighbourhood-level; this included socio-economic deprivation level from the SAIMD.

The deprivation variable was created from deciles of SAIMD rank data. This variable was binary, whereby SAIMD rank decile values of 1 to 5 were classified as most deprived, and values of 6 to 10 were classified as least deprived. Most deprived was designated as 1 and least deprived as 0. The speed limit variable was created as binary, with the speed limit over 60 km/h designated as 1, and speed limit equal to or below 60 km/h designated as 0. The LanesPerRoad variable was created as binary, where a one lane road was designated as 0 and roads with more than one lane as 1. The direction of the moving vehicle in a one lane road decreases the risk of transport-related incidents compared to roads with more than one lane.

5.6 Results

In this thesis, there were 194 transport-related injury incidents recorded from 2011 to 2015. The data highlighted that most transport-related deaths increased over time of day and peaked at 5 pm in the afternoon (10.2 %) (Figure 5.2).

Figure 5.2

Number of transport incidents by time of day, 2011-2015; Metro West, CoCT

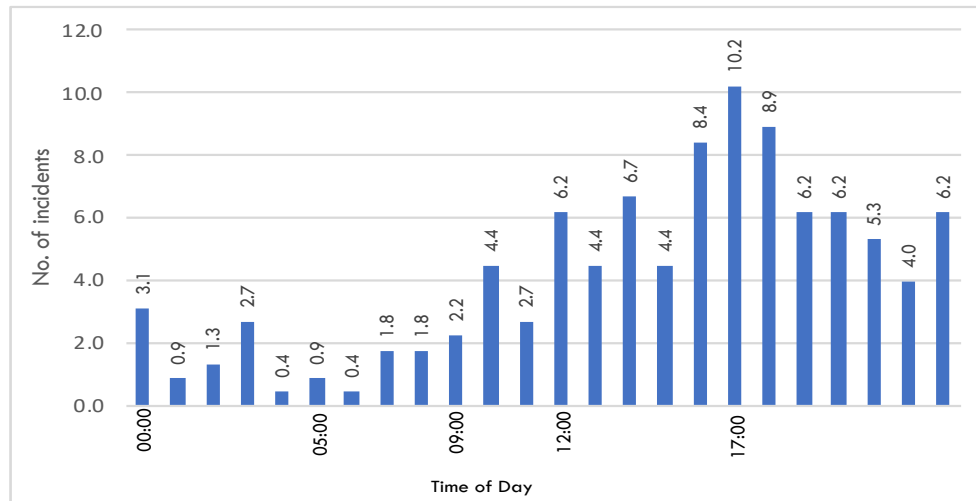
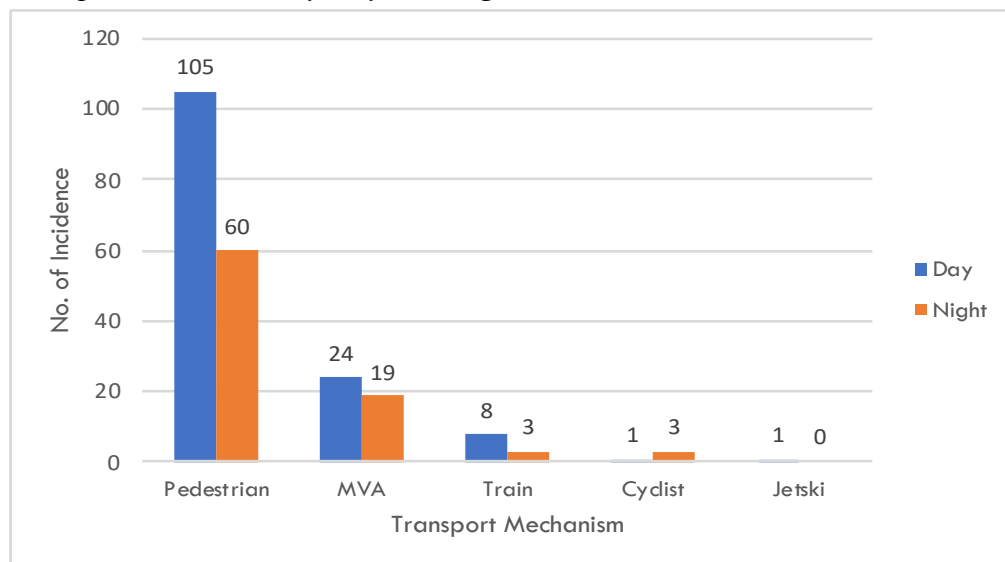


Figure 5.3

Transport mechanism by Day and Night

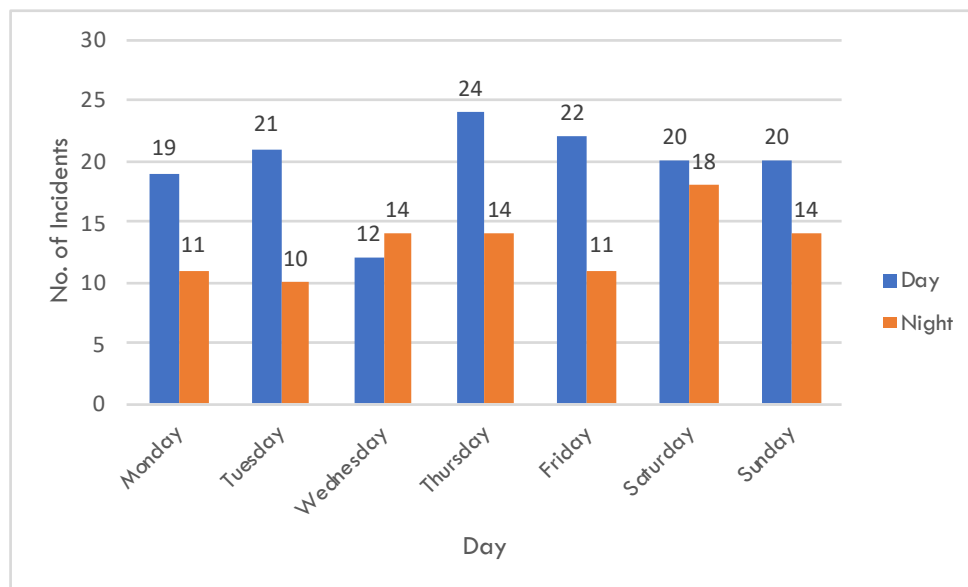


Each mechanism of transport was categorised into day and night (Figure 5.3). Most transport related injury deaths occurred during the daytime except for cyclists. Pedestrian related injury deaths represented 73.6 % of all deaths occurring during the daytime.

Figure 5.4 represents the day of the week that a transport related death took place. Most deaths took place on a Thursday (16.5 %) or on a Saturday (16.5 %), followed by a Sunday (14.8 %) then a Friday (14.3 %). With respect to age group, children younger than 9 years were most at risk, representing 64.1 % of the total deaths.

Figure 5.4

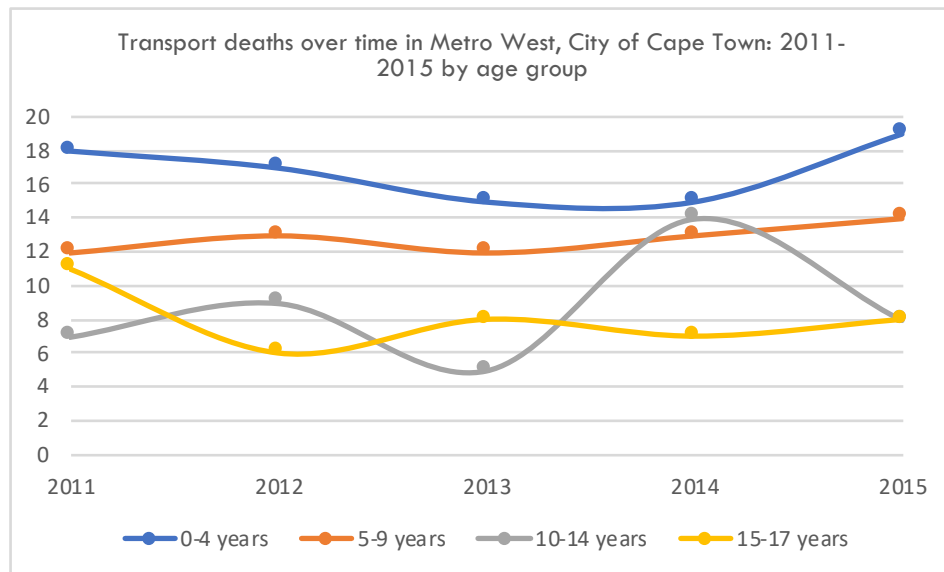
Transport deaths for every day of the week by day and night for children aged 0-17 years, 2011-2015; Metro West, CoCT



A similar pattern was observed over time in years (Figure 5.5).

Figure 5.5

Transport deaths by age group (0-17 years) over time, 2011-2015; Metro West, CoCT



The choropleth map highlights the deprivation score of each suburb (Figure 5.6). The most deprived suburbs were in the Western and Mitchells Plain sub-health districts. The least deprived suburbs were in and around the city centre.

Figure 5.6

Choropleth map highlights the deprivation score of each ward, 2011-2015; Metro West, CoCT

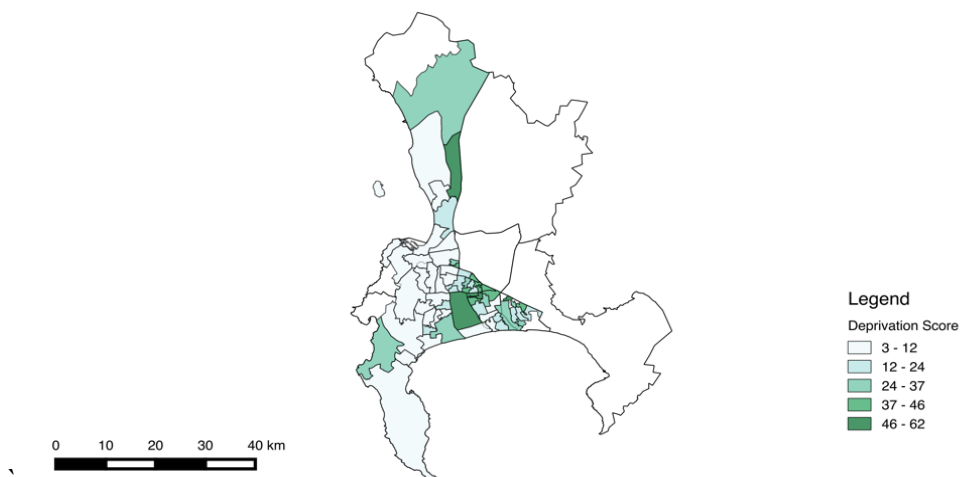
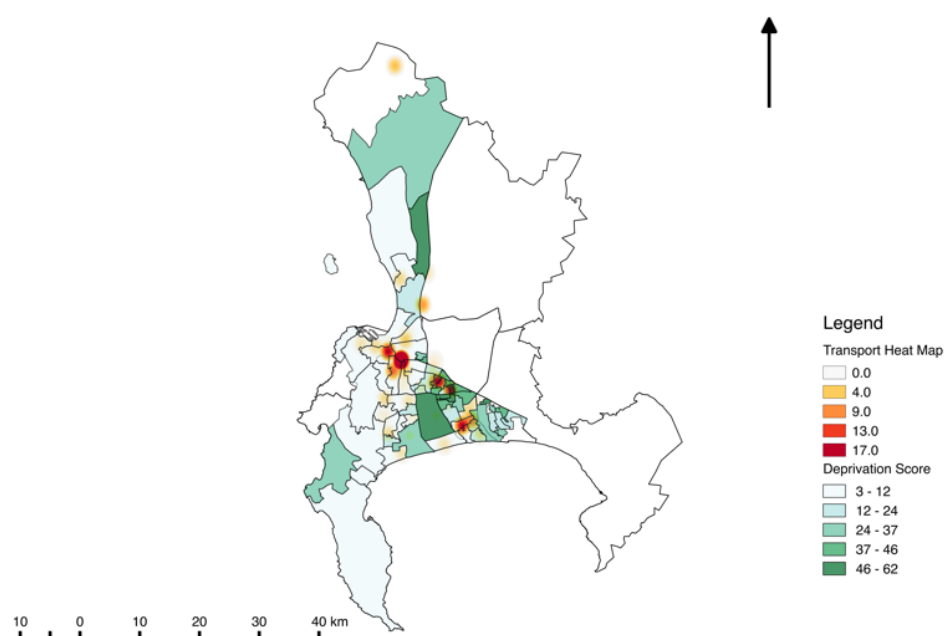


Figure 5.7 represents the transport-related death heat map. Of the three clusters indicating a high density of transport-related deaths (dark red), only two are located within suburbs that have a high deprivation score (dark green). The most densely highlighted area is located within a suburb that has the lowest deprivation score.

Figure 5.7

Heat map representing transport deaths of children aged 0-17 years and deprivation score for each ward, 2011-2015; Metro West, CoCT



5.6.1 Spatial Scan Statistic: Transport Fatality Hotspot

One primary and three secondary transport fatality clusters with a radius of less than 1km were detected. Based on the Monte Carlo hypothesis testing, the SatScan identified a primary cluster ($RR = 221.4$, $p < .001$) for Mowbray, suggesting it had the highest likelihood of a cluster of transport-related deaths occurring (Table 5.2). The secondary clusters had risk ratios ranging from 5.6 to 245.8 and were significantly different.

Table 5.2

Characteristics of detected clusters of all transport deaths, 2011-2015; Metro West, CoCT

Cluster & Location	No of observed cases	No of expected cases	RR	P-value
1. Mowbray	11	0.05	221.4	0.001
2. Observatory	8	0.13	63.8	0.001
3. Strandfontein	2	0.002	245.8	0.006
4. Nyanga	8	1.4	5.6	0.019
5. Ottery	2	0.069	29.2	0.22

6. Philippi East	6	1.52	4.1	0.45
7. Manenberg	5	1.51	3.4	0.92
8. Mandalay	2	0.24	8.4	0.94
9. Wynberg	2	0.27	2.3	0.97

A discrete Poisson analysis highlighting four significant clusters was performed using transport fatality data (Table 5.2). These clusters were in Mowbray ($p < .001$), Observatory ($p < .001$), Strandfontein ($p < .05$), and Nyanga ($p = .019$). Mowbray is one of the most deprived suburbs, with a deprivation score of 3830 and a significant transport cluster; by comparison, Mitchells Plain has a low deprivation score (2485) (Figure 5.8).

Spatial regression analysis was performed in R for all fatal transport cases from 2011 to 2015. In Figure 5.9, the fatal transport rate was mapped, with suburbs located in the Klipfontein sub-health district reporting the highest rate.

Figure 5.8

Deprivation score by ward and transport-fatality of children aged 0-17 years clusters of 1km radius, 2011-2015; Metro West, CoCT

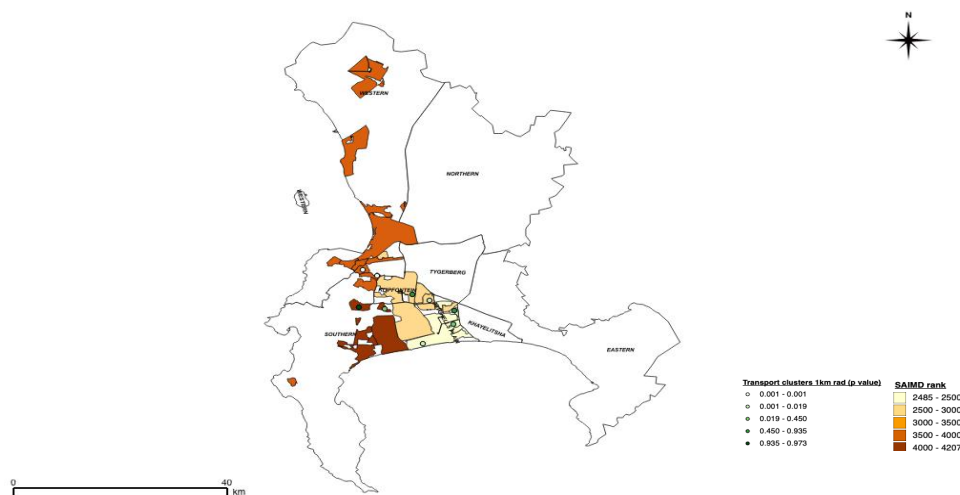


Figure 5.9

Fatal transport rate for children aged 0-17 years by suburb of interest, 2011-2015; Metro West, CoCT

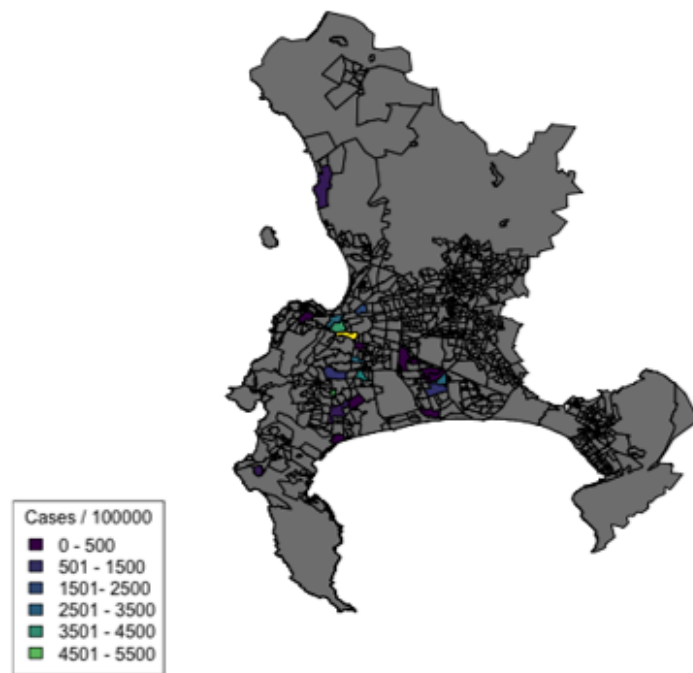


Table 5.3

Representation of univariate (independent model) analysis for each explanatory variable (predictor), 2011-2015; Metro West, CoCT

Variable Name	Description	N	Mean	SE	95% CI	P-Value	AIC value
IRfemales	Female transport deaths per 100,000 female population	24	297.4	208.6	-134.2-729.1	<0.01	338.83
IRmales	Males transport deaths per 100,000 male population	24	592.8	230.04	116.9-1068.7	<0.00000000000001	315.44
IR_U5	Under-five transport deaths per 100,000 under-five population	24	371.6	229.8	-103.8-846.9	<0.002	336.56
IR5_9Y	5-9 years transport deaths per 100,000 5-9 year population	24	259.4	166.9	-85.9-604.8	0.05	341.83
IR10_14Y	10-14 years transport deaths per 100,000 10-14 year population	24	273.4	198.3	-136.9-683.6	<0.01	337.65
IR15_17Y	15-17 years transport deaths per 100,000 15-17 year population	24	332.6	202.6	-85.6-751.9	0.3	347.33
EduDep	Education Deprivation Score	24	9.2	1.3	6.4-11.8	<0.000001	333.13
MatDep	Material Deprivation Score	24	13.9	3.04	7.6-20.2	<0.01	344.84
EmployDep	Employment Deprivation Score	24	20.7	2.8	14.8-26.6	<0.00001	338.83
LivingEnvironment	Living Environment Deprivation Score	24	11.8	3.1	5.3-18.2	<0.0001	341.93
SAIMD	Overall SAIMD Score	24	27.9	6.8	13.8-42.04	<0.001	341.75
NrLanes	Binary: Number of Lanes	24				0.418	348.91
AveSpeedLimit	Binary: Average Speed Limit	24				0.418	348.91
Deprivation	Binary : More or less deprived area	24				<0.0000001	330.14

The NB regression for each individual independent variable had a value of $p < .05$ for the following variables per 100,000: transport fatality rate for females aged 0 to 17 years, transport fatality rate for children younger than 5 years, transport fatality rate for children aged 5 to 9 years old, transport fatality rate for children aged 10 to 14 years old, education deprivation

score, material deprivation score, employment deprivation score, living environment deprivation score, deprivation, and Overall SAIMD score.

Table 5.3, represents descriptive statistics, p value, and Akaike Information Criterion (AIC) value for each univariate independent model: Only variables that displayed a statistically significant relationship with the overall transport mortality rate were included in the final model. The AIC value represents the fit of the model, with models having the lowest AIC values considered the best fit. Therefore, both the p value and AIC value are considered before final models are established.

Following several combinations of variables with comparing AIC values, the final NB demographic model was established. This model included the males' transport-related injury mortality rate and the transport-related injury mortality rate for age groups 5 to 9 years and 10 to 14 years (Table 5.3). Two variables were excluded since they were no longer significant, at $p < .05$, when combined with other variables. The results from the final NB demographic model suggested that with every 10% increase in transport-related mortality rate for males, the overall transport-related injury rate increased by 4.3%. A similar result was observed for the overall transport-related injury mortality rate, when the transport-related injury mortality rate increased by 10% for children aged 5 to 9 years and 10 to 14 years (Table 5.4).

Table 5.4

Multivariate NB model with demographic variables

Parameter	Sig.	Exp(B)	SE	Z value
(Intercept)	2.00E-16	4.3	0.14	29.4
IRmales	2.00E-16	0.0021	0.00022	9.4
IR5_9	7.20E-05	0.0015	0.00038	3.9
IR10_14Y	6.90E-08	-0.0024	0.00045	-5.4

To determine the impact of socio-economic variables on the overall transport-injury mortality rate, several NB models were tested. When all the socio-economic variables were placed in one model, only the deprivation variable generated a significant relationship with the dependent variable. The individual deprivation NB model was selected as the final SES model because it had the highest p value ($< .0000001$) and lowest AIC (330.14) compared to all the other SES variables. The results highlighted that living in a less deprived suburb decreases the likelihood of overall transport-related mortality by 2.2 ($p < .0000001$).

From the ANOVA test results (Table 5.5), comparing the NB model with and without each explanatory variable suggests that these variables are significant predictors of overall transport-related injury mortality rate.

Table 5.5

Results from ANOVA test for NB model

Dependent variable: Overall Transport Injury Mortality rate	NB Model		
	RR	95 percent CI	P-Chi
IRmales	1.5	1.6e-3 – 2.6e-2	1.50E-05
IR5_9	2	7.5e-4 – 2.3e-2	0.00074
IR10_14	1.5	-3.4e-3–(-1.4e-3)	1.50E-05

5.6.2 Spatial Dependency and Injury Mortality Rate

To test the dependency of both NB models, overall transport-related injury mortality is correlated with outcomes of its neighbours (conditional to other variables). If no spatial dependency is present, then the NB model is used. In this thesis, the Moran I was used to test the null hypothesis that there is no spatial dependency in our dataset. Additional models, i.e., spatial lag and spatial error, were employed to assess spatial dependency.

Table 5.6

Spatial regression Models for demographic variables

Dependent Variable: Overall Transport Injury Mortality rate	NB Model		Spatial Lag Model		Spatial Error Model	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
IRmales	0.0021***	0.00022	0.870***	0.044	0.868***	0.044
IR5-9	0.0015***	0.00038	0.52***	0.078	0.521***	0.078
IR10-14	-0.0024***	0.00045	-0.28**	0.091	-0.282**	0.09
Number of Obs (n)	25		25		25	
Log Likelihood	-290.41		-147.88		-147.92	
AIC	300.41		306.1		307.8	
Wald Test(df=1)			0.311		0.229	
LR Test(df=1)			0.302		0.214	

Note: $p < .01$ *** | $p < .05$ **

Results from the Moran I test found that the test statistic was 6.03 and the p value was $8.04e^{-10}$; therefore the null hypothesis was rejected. The type of spatial dependency, spatial lag, and spatial error were then tested (Table 5.6; Table 5.7).

Table 5.7

Spatial regression Models for SES variables

Dependent Variable: Overall Transport Injury Mortality rate	NB Model		Spatial Lag Model		Spatial Error Model	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Deprivation	-2.28***	0.429	-1065.2**	374.4	-1064.7**	374.1
Number of Obs (n)	24		24		24	
Log Likelihood	-324.14		-197.4		-197.4	
AIC	330.1		400.8		402.8	
Wald Test(df=1)			0.00153		0.00306	
LR Test(df=1)			0.000415		0.00236	

Note: $p < .01$ *** | $p < .05$

Once these models had been assessed, tests were carried out to determine which spatial dependency model was the best fit for the data relative to the NB model, by using the Lagrange Multiplier (LM) tests (Anselin et al., 1996). The results for the spatial regression models using the demographic variables showed that the LMlag statistic was 0.0106 with $p = .9179$, while the LMerr was 0.142 with $p = .706$. Therefore, the NB model was preferred.

However, for both LMlag and LMerr tests, spatial errors can still be present with no lags (and vice versa for the LMerr test). To determine if spatial errors are present with spatial lags, additional tests are performed. The RLMerr statistic was 0.14 with $p = .706$, while the RLMlag statistic was 0.10 with $p = .915$. Therefore, we failed to reject the null hypothesis that spatial errors are possible in the presence of spatial lags. The NB demographic model was the best fit compared to the spatial lag and spatial error demographic models. Similarly, the NB for deprivation model was a better fit.

Based on the results, outcomes from the spatial lag model for both demographic variables and SES are described. In the spatial lag model for demographic variables, the relationship between

all the explanatory variables and dependent variables remains statistically significant. Positive relationships observed for IRmales and IR5_9, and negative relationships with IR10-14Y was observed. The spatial lag parameter (ρ) is small (-0.108) with $p = .302$. The negative value of ρ indicates a negative spatial feedback effect, thus when the total transport-related injury mortality rate decreases, it is predicted that a similar effect would apply to its neighbours (locations near to points in the dataset).

5.7 Discussion

This thesis found that the spatio-temporal distribution of child transport injury deaths was predominately in areas that were least deprived and occurred during the daytime. Spatial risk factors that influenced the likelihood of RTC mortality were gender, low level of deprivation, and the 5 to 14 years age group. This thesis found that most transport incidents occurred between 4 p.m. and 6 p.m. on Thursdays and Saturdays. According to Kingham et al. (2011), most transport incidents in Christchurch, New Zealand occurred between 7.45 a.m. and 8.30 a.m. and between 4.30 p.m. and 5 p.m., both traffic rush hour periods. Peak traffic across nearly every road in the CoCT on weekdays occurs between 5 p.m. and 6 p.m. This would suggest that during these times, most caregivers are on their way home and their children are not safe.

Over a period of 5 years (i.e., 2011 to 2015), this thesis found that the number of transport deaths for each age group had remained constant except for the 10 to 14 years age group where the case count increased in 2014.

Based on the heat map analysis, there were four clusters that demonstrated a high density of transport deaths. These four clusters were mainly located in wards that had a low deprivation score. Furthermore, when determining significant pedestrian clusters over time, there was only one significant cluster, located in the Southern sub-health district, which did not overlap with results from the heat map. Additionally, this thesis found that least deprived areas were a strong predictor of transport-related mortality for children aged 0 to 17 years. Therefore, areas that had high material deprivation, employment deprivation, education deprivation, and living environment deprivation were more likely to have high levels of transport-related mortality in children aged 0 to 17 years. This evidence suggests that children living in deprived areas are at risk of being involved in an RTC. According to Noble et al. (2013), the Western Cape Province is the least deprived province based on data from the 2011 Census. However, there are

geographical areas within the province which are more deprived than others. The deprivation score depends on living environment deprivation, education deprivation, employment deprivation, and material deprivation (Noble et al., 2013).

This thesis found that there was a significant risk of transport-related mortality if the child was male; aged either 5 to 9 years or 10 – to 14 years; and lived in a deprived suburb. These four explanatory variables on their own (except for the deprived variable), and in combination with other explanatory variables in the final models, were strong predictors of transport-related mortality. The explanatory variables, “speed limit and number of lanes, were not significant predictors of transport-related mortality in children at the suburb level even when added to other predictors in the SES model.

Speeding is a major risk factor of transport-related mortality, specifically RTC incidents. A study in Nigeria, using NB regression to determine the likelihood of a crash, found that over speeding, i.e., driving over the speed limit, significantly increased the risk of an RTC by 7.7% (Uchendu et al., 2021). Additionally, Brubacher et al., (2016a) found that roads with speed limits of 60 km/h or less had higher incidence of fatal speed-related crashes, which is typical in urban areas. In this thesis, all transport-related fatalities occurred on roads that had a speed limit of 60 km/h except one road that had a speed limit of 120 km/h, implying that during the fatal incident, the motor vehicle was driving faster than the speed limit. According to WHO, when a vehicle travels at 80 km/h and knocks an adult pedestrian, the risk of death is 100%; however, at 30 km/h, the pedestrian survival rate increases by 90 % although the risk of death is higher in children (World Health Organization, 2004).

This thesis found that males were a strong predictor of transport-related mortality across age groups. Similarly, according to Mitchell et al. (2018), from 2001 to 2012 using NB regression, males were found to be a strong predictor of hospitalisation following an RTC incident. This is likely due to males' risky behaviour compared to females (Turner & McClure, 2003). In addition to gender, the age of the child also plays a role as a predictor of transport-related mortality. This thesis found that compared to children younger than 5 years or than 14 years, children aged from 5 to 14 years were a stronger predictor of transport-related mortality relative to location of transport incident. In 2020, a study in Johannesburg, South Africa found that areas with high levels of deprivation reported elevated pedestrian deaths, especially in children

aged from 5 to 9 years (Bulbulia et al., 2020). This suggests that children living in these deprived areas are more likely to be exposed to inadequate road infrastructure that lack safety features like raised sidewalks or bridges over major highways (Green et al., 2011; Ribbens et al., 2008). Furthermore, children aged from 5 to 9 years lack the skills needed to navigate traffic flow and vehicle speed, therefore increasing the likelihood of an RTC (Rivara, 1995). As children become older, they gain more experience in navigating complex road environments such as evaluating when it is safe to cross a busy street (Bulbulia et al., 2020).

5.8 Study Limitations

Where the injury took place, i.e., non-fatal injury death especially for cases with the death location specified as Mowbray (these more likely occurred at Red Cross Hospital). This does not provide a clear picture of the burden of transport deaths located within the municipality but does indicate the burden (resources – people, money, time) taken on by health facilities when a child dies from a transport death which is preventable.

Data that had missing SAIMD data was removed (n=1). We were unable to map the residual and estimation of each model (NB, spatial lag, spatial error) for both demography and deprivation by linking these values to the study shapefile.

Due to non-significant relationship between the explanatory variables, number of lanes and speed limit, with the dependent variable, they were excluded from the models. Both variables are important risk factors that influence RTC burden. During a pedestrian collision the vehicle speed influences the severity of injury or the likelihood of death. Thus if a vehicle is driving faster than the speed limit (60 km/h) in suburban areas; the pedestrians are most likely to incur severe injury or death.

5.9 Conclusion

This thesis found that the level of deprivation was a strong predictor of transport-related mortality, with areas that had a high deprivation score reporting fewer injuries than areas of low deprivation score. A similar pattern was observed with the gender and age of the child, as well as the time of day the incident occurred. The findings of this thesis are in line with other research conducted both globally and locally, with males and children aged from 5 to 9 years and from 10 to 14 years, increasing the risk of a fatal transport-related incident occurring.

Furthermore, this thesis found that most transport-related fatalities occurred on Thursdays in the late afternoon, during peak traffic hours, and on Saturdays when caregivers left their children unsupervised. The study highlighted the importance of assessing the association between the spatial distribution and socio-economic factors that influence transport-related fatality, and identified the areas that needed child-centred interventions to prevent these deaths. The results suggest that to prevent transport-related fatalities in children and to keep them safe, road infrastructure needs to be of a high standard and well maintained. There should be reliable data on speed limits, which must be enforced at all times. In addition, to gain a deeper understanding of the influence of risk factors on transport-related mortality affecting children, reliable data on lighting on the road and width of lanes is needed.

Chapter 6: Morbidity and mortality from road traffic crashes in children in Metro West, City of Cape Town, 2014

6.1 Background

6.1.1 Road Traffic Crash Injury Burden

Globally, RTCs are one of the leading causes of death (COD) in both adults and children and represent the largest percentage of injury death in children older than 5 years (Institute for Health Metrics and Evaluation, 2021). The global RTC mortality rate among children has declined over the last decade (2009 to 2019) (Institute for Health Metrics and Evaluation, 2021). Several factors play a key role in the incidence of RTCs; these include the child's age and income level of a country. As children become older the likelihood of an RTC incident increases, with children aged 5 to 9 years most at risk (Institute for Health Metrics and Evaluation, 2021).

Children in this age group have a higher risk of being involved in an RTC incident if they live in a low-income country. HICs reported the lowest RTC mortality rate in 2019 across all age groups compared to LMICs and UMICs; for example, the Central African Republic, a low-income country, reported the highest RTC fatality rate for children over this period (HICs) (Institute for Health Metrics and Evaluation, 2021). This high fatality rate can be attributed to pedestrians being in close proximity to high traffic volumes due to lack of sidewalks, and vehicles travelling at high speeds (Guerrero et al., 2011; Zimmerman et al., 2012). The disparity between HICs and LMICs is largely due to greater resource allocation in HICs to prevent RTC deaths. This includes adequate funding to improve road infrastructure, town planning to ensure road safety, enforcement of road traffic laws and safety of vehicles, and effective campaigns to educate the public on road safety (World Bank, 2020). Although the non-fatal RTC injury burden in both HICs and LMICs has continued to increase over the past decade (2007 to 2017), global RTCs (mortality and morbidity) have declined over the same period.

Globally, the RTC mortality rate in children younger than 18 years differs by the mechanism of injury (pedestrian, passenger, or cyclist). Children are more likely to die due to a pedestrian RTC compared to any other mechanism of injury (Institute for Health Metrics and Evaluation, 2021). This pattern of RTC mortality is observed across LMICs and UMICs; whereas in HICs, children are more likely to die as a result of passenger RTC (Institute for Health Metrics and

Evaluation, 2021). This high global pedestrian fatality rate in children is driven by the high pedestrian fatality rate in LMICs, which accounts for nearly 90% of the global child pedestrian fatalities (Institute for Health Metrics and Evaluation, 2021). By comparison, the low pedestrian fatality rate for children in HICs and UMICs can be attributed to good road safety practices such as pedestrian friendly road designs; traffic free residential areas and fenced off recreational facilities like parks; active law enforcement; and a shared vision by stakeholders to reduce RTC fatalities. For example, Swedish Vision Zero which aimed to reduce RTC fatalities by improving the road traffic environment had complete buy-in by the Swedish government and other stakeholders (Belin et al., 2012; de Keersmaecker, 2020; World Bank, 2020).

South Africa reported an RTC mortality rate of 7 per 100,000 for children aged 0 to 14 years in 2017 (Prinsloo et al., 2021), which was lower than Botswana (12.5 per 100,000) but slightly higher than Namibia (6 per 100,000) over this period (Institute for Health Metrics and Evaluation, 2021). From 2008 to 2011, majority of children living in Gauteng, South Africa who were involved in an RTC were aged 6 to 12 years (50.9 %), 3 to 6 years (46.9%) and 1 to 3 years (33.8 %) (Pretorius & Van Niekerk, 2015). The same age groups were involved in a fatal pedestrian incidents (Pretorius & Van Niekerk, 2015). South Africa, a UMIC, reported a pedestrian fatality rate of 8.3 in 2017 compared to only 6.4 in Namibia and 4.2 in Botswana, both of which are also UMICs (Institute for Health Metrics and Evaluation, 2021).

6.1.2 *RTC Risk Factors*

Several risk factors drive the RTC injury burden among vulnerable populations like children (World Health Organization, 2012). The main risk factors relating to children include age, gender, SES, and child supervision. Other important risk factors are related to roads, speed, and law enforcement.

6.1.2.1 Age

The age of a child plays a crucial role in the RTC burden. This includes the child's physical characteristics, such as smaller stature and anatomical structure; lower cognitive development; and peer pressure (Peden, 2008). Young children are small, making them more difficult to see on the road; for example, findings from the CDR Project in Cape Town highlighted cases where young children were accidentally run over (forward driving and reversing) while playing in a

driveway. Small children may not be visible to a driver when they are playing on a pavement that is not high enough to keep them away from the road (Mathews S, 2014). In addition to their small stature, children's visual, hearing, and intellectual capabilities are only optimal from 10 years of age (Whitebread & Neilson, 2000). Consequently, younger children are more likely to be distracted and not focussed and may miss critical danger cues, such as the speed of oncoming traffic, when playing outside. They may also not understand how to avoid a collision with a vehicle. Lack of safe recreational spaces, especially in deprived areas, increases the risk of children being involved in an RTC. School age children in South Africa, like their peers globally, are most at risk of being involved in an RTC, as most walk for several kilometres to and from school.

Although adolescent children are more capable of assessing critical danger cues than younger children, they are more likely to engage in risky behaviour such as running across a busy road; dodging oncoming traffic; and hanging on the back of vehicles to impress their friends. This could lead to adverse outcomes such as injury. Evidence suggests that adolescents seek out experiences that maintain a high-level of physiological excitement as described above.

6.1.2.2 Gender

Gender has been found to influence the likelihood of an injury, with males more at risk than females (Peden, 2008). Globally, more than 90 % of RTCs involved males (Institute for Health Metrics and Evaluation, 2021). Male children are more competitive and take more risks than female children, increasing their risk for RTC injury (Waylen & McKenna, 2008). Studies have found that the behaviour of male children, specifically their thrill-seeking behaviour and peer influence is the greatest contributor to RTCs. This behaviour results in more male children being involved in a severe injury or death than female children. At the onset of adolescence, children's decisions are more likely to be influenced by their friends than by their parents. This peer influence may encourage them to engage in high-risk behaviour as they seek to impress their friends. This impulsive decision-making, such as trying to cross a busy road instead of using a pedestrian crossing or bridge, is prevalent in males in this age group and increases the likelihood of pedestrian incidents.

Injuries related to RTC incidence are a complex web of inter-related risk factors. Young children, especially males, are more at likely to be involved in an RTC incident due to their

risk-taking behaviour. Children that lack supervision, especially in deprived areas with limited appropriate road safety infrastructure, are at greater risk of being in a pedestrian incidence.

6.1.3 *RTC Interventions to Manage the Burden*

Road safety interventions differ depending on the country, with some only focusing on one type, such as legislation, and others utilising a multi-pronged approach. The WHO recommends various road safety interventions that are based on implementing legislation and enforcing road traffic laws regarding user behaviour, safer roads and mobility, safer vehicles, and post-crash care (WHO, 2006). Over the last decade, most LMICs have experienced a steady increase in the number of RTC incidents (Institute for Health Metrics and Evaluation, 2021). This can be attributed to the increase in traffic density and motorisation. First-generation motor vehicle drivers and increased urbanisation also play a significant role. In addition, town planning, design of new or upgraded residential areas, maintenance of road infrastructure and enforcement of road traffic laws and regulations do not adequately consider the needs of vulnerable road users, such as pedestrians (World Health Organization, 2006). Road safety interventions in LMICs are predominantly focused on the enforcement of legislation or improving public awareness to address the RTC burden (Staton et al., 2016). Resource-rich countries like Sweden have continuously experienced low RTC mortality rates due to good road safety practices such as redesigning roads with mid-and side-barriers and enforcing a 30 km/h speed limit in residential areas (Johansson, 2009). LMICs have high RTC mortality rates and lack infrastructural measures such as limited raised side-walks that separate pedestrians from traffic (Khan et al., 2015; United Nations, 2013). Therefore, to successfully reduce RTC incidents, countries should adopt a combined approach. This should include prioritising pedestrian safety in the redesign of roads in residential areas, implementing speed limits to reduce RTCs and injury severity, and adopting interventions to change behaviour such as speeding and driving under the influence of alcohol.

The Haddon Matrix (Table 6.1) is a guiding framework for preventing RTC morbidity and mortality. It is a tool that systematically analyses RTC risk, by identifying factors that contribute to fatal crashes or severe injury, in order to assist in developing and prioritising preventative measures that reduce RTC injuries (Runyan, 1998). There are three phases: pre-event, event, and post-event. The pre-event phase includes factors associated with preventing injury or reducing the injury severity (WHO, 2006).

Table 6.1

Adapted Haddon Matrix from (Peden, 2008) - Applied to the risk factors for RTC injuries among children in South Africa

Pre-event	Age; gender; lack of supervision; risk-taking behaviour; impulsive behaviour; disobedience; lack of police enforcement	Lack of roadworthiness of vehicle; poor lighting; poor state of brakes; speeding; overloading of vehicles. Unregulated and unsafe vehicle design.	Poor road design; lack of public transport; no enforcement of speed limits; no safety barriers; lack of alcohol laws; poor infrastructure for pedestrian safety i.e. separating pedestrians from motorised, non-motorised vehicles, and mass transport).	Poverty; single-parent family; large family size; poor maternal education; lack of awareness of risks among caregivers, childcare providers and educators; substance abuse, aggressive driving, distractions; residence located far from employment, services, and educational institutions
Event	Size and physical development of child (hearing, vision, attention, physical and emotional maturity, inexperience); lack of equipment to protect occupants, or equipment improperly used; underlying conditions in child.	Child restraints and seat-belts not fitted or incorrectly used; bicycle and motorcycle helmets not used; poor design of vehicle for protection in crashes.	Roadside objects such as trees and poles; lack of access to healthcare facilities; inadequate ambulance provision due to ambulances being hijacked. Pot-holes present in the road. Median and multiple carriageways.	Lack of road safety culture in the car and on the road. Lack of road safety knowledge being taught in schools. Speeding, disobeying rules, taking risks; cell phone use. Lawlessness and ineffective enforcement of road traffic rules especially minibus taxi and luxury vehicle drivers. Irresponsible advertising promoting speeding; aggressive tailgating
Post-event	Child's lack of resilience; child's general condition; lack of access to appropriate health care; post-injury complications.	Difficult access to victims; lack of trained health-care and rescue workers.	Lack of availability of adequate pre-hospital care, acute care and rehabilitation. Lack of investment to improve road infrastructure which will reduce traffic density and improve lighting on the road.	Lack of culture of supporting injured people; no first aid given at scene.

Several road safety initiatives have been implemented across the Western Cape, South Africa, to reduce the RTC burden by changing individual behaviour. These initiatives include tackling over speeding, one of the major risk factors influencing the RTC burden. Implementing the average speed enforcement system on provincial roads, such as the R61 heading towards Beaufort-West, resulted in a significant reduction of RTC fatalities and severe injury (Akpa et al., 2016). Upgrading the road infrastructure by building traffic-calming measures, such as speed bumps near schools in Durban, reduced pedestrian-vehicle collisions by 23% (Nadesan-Reddy & Knight, 2013). In 2018, the CoCT deployed random breathalysing testing of drivers across the city to reduce cases of driving under the influence of alcohol (Smith JP, 2018). In 2019, the city offered free vehicle safety checks at vehicle testing stations before the Christmas holiday, when many South Africans travel across the country heading home or going on vacation (Smith JP, 2018). The implementation of these initiatives possibly influenced the RTC fatality rate in the Western Cape, which saw a decline in RTC crashes and fatalities (Road Traffic Management Corporation, 2020).

Other African countries have predominantly used health education interventions to change individual behaviour; specifically, media campaigns, which raise awareness about RTC incidents. From 2011 to 2013, a longitudinal study was conducted by Habyarimana and Jack (2015) involving 12,000 minibuses in Matutu, Kenya, to determine if evocative messages on stickers placed inside minibuses could directly change individual passenger behaviour, followed by indirectly changing driver safety behaviour to reduce RTCs. The study found that compared to than drivers who did not have the stickers in their minibuses, drivers in the intervention arm were involved in fewer accidents and did not drive over the speed limit (Habyarimana & Jack, 2015). This evidence suggests passengers could potentially influence driver behaviour and the likelihood of a RTC occurring.

In South Africa, the Arrive Alive campaign, a government supported national platform that promotes road safety and public awareness, has significantly contributed to the national road safety response. It actively promotes road safety geared towards drivers, vehicles, driving, and enforcement of road traffic laws (Arrive Alive, 2022).

Several partnerships have been made with Arrive Alive to further promote road safety; this includes the Road Accident Fund, Imperial, Netstar, and OUTsurance. The support from these prominent entities has significantly increased road danger awareness by contributing to surveillance efforts in collecting, storing, and disseminating RTC injury information to the public.

In a study to determine the cost effectiveness of increasing traffic enforcement in Uganda from 2001 to 2005, Bishai et al. (2008)) found that RTC fatalities decreased by 17% after the deployment of traffic officers who enforced the road rules along four main roads leading to Kampala city every day of the week from 6 a.m. to 6.30 p.m. The authors found that enforcing road rules was a cost-effective strategy to reduce the RTC burden in Kampala City, which equated to \$27 (R398.2) per life year savings discounted at 3% (Bishai et al., 2008).

Preventative interventions should relate to the five pillars of road safety namely being comprehensive, multi-pronged, sustainable, able to maintain health benefits over a period, and cost-effective.

6.1.4 RTC Policy Environment

The Decade of Action for Road Safety 2011-2020 was officially proclaimed by the United Nations General Assembly in March 2010 to provide countries with a framework to guide the development of road safety activities (World Health Organization, 2012). There are five pillars of the Decade of Action for Road Safety 2011-2020:

- i. Road safety management (i.e., legislation, enforcement, and engagement with the justice system)
- ii. Safer vehicles (i.e., improving safety standards)
- iii. Safer roads and mobility (i.e., safe road infrastructure)
- iv. Safer road users (i.e., addressing needs of vulnerable road users, speed management)
- v. Post-crash response (i.e., train staff the appropriate road safety practices, trauma care and rehabilitation)

Since the Decade of Action for Road Safety 2011-2020 was initiated, RTC deaths have increased globally, especially in LMICs (Institute for Health Metrics and Evaluation, 2021). Several African countries have implemented RTC preventative interventions to change individual behaviour with an aim to reduce RTC deaths; however, this has not been the case. This could be due to lack of traffic laws enforcement and an increase in vehicle density without road infrastructure improvement to accommodate these changes. In South Africa, the number of registered vehicles increased from 10,193,050 in 2011 (Road Traffic Management Corporation, 2011) to 12,462,979 in 2018; however, the nationwide RTC mortality rate declined during this period (Road Traffic Management Corporation, 2018). During the same period, Gauteng and the Western Cape Province accounted for more than 50 % of the vehicles registered in South Africa, with only a slight decline in road fatalities (Road Traffic Management Corporation, 2019).

In 2015, South Africa introduced the National Learner Transport policy to provide safer transportation for all learners. This policy was predominately implemented in rural areas where access to public transport is limited and road infrastructure poor (Department of Transport, 2015). Since the implementation of this policy, more than 574,000 school-going children have access to safe transport services to shuttle them to school and back home as of March 2018 (Phosa Y, 2018). However, several challenges remain; this include the continued use of private transportation; a lack of formal scholarly transport provided by the Department of Transport;

insufficient funding for remunerating transport providers; and a lack of uniformity in contracting and remunerating drivers.

Since road safety is a major global public health crisis, two SDGs were created to enhance the Decade of Action for Road Safety activities, with the aim of halving the number of road traffic deaths and injuries by the year 2020, and to improving road safety (Griggs et al., 2013).

6.2 Specific Objectives

The aim of this thesis was to assess fatal and non-fatal RTCs for children younger than 13 years of age, stratified by age, gender and mechanism of RTC within the Metro-West, CoCT, from 1 January until 31 December 2014. This period was selected as it represents the data collected from the pilot phase of the CDR study. To provide a more in-depth understanding of the RTC burden and area of interest over this period, morbidity data was included to determine the YLD followed, by an RTC incident relative to the nature of injury across age groups. Additionally, a multiple regression analysis was performed to determine which factors impacted hospital admission for non-fatal RTC incidents.

6.3 Specific Methods

A secondary data analysis was performed from two complementary datasets, RTC fatalities (2014 pilot CDR project, SRM mortuary); and non-fatal injury data of children utilising the Childsafe South Africa (CSA) database, trauma unit, RCCH.

The CDR study retrospectively reviewed all deaths of children younger than 18 years of age that was presented to SRM. Data from each child death presented to a medico-legal mortuary was systematically collected using an inter-sectoral collaborative approach. However, the most important aspect of the CDR process was the multi-disciplinary team with representatives from law enforcement, social services, health, and prosecution services met retrospectively reviewing the circumstances surrounding each child's death (Mathews et al., 2016). CDR teams met monthly to review all child deaths that generated a standardised response to the investigation, especially in case of sudden, unexpected deaths. The demographics, medical history, and COD data were collected and captured in a standardised manner. During the monthly review, the forensic pathologist led the discussion with the team members who had

all signed confidentiality agreements. The aim of the review was to identify which events led to the death of the child with regard to medical history and police investigation (Mathews et al., 2016). Following a discussion, where additional information was required, it was the team's mandate to determine if the death was preventable by evaluating the potential factors influencing the death (Mathews et al., 2016).

This thesis's data comprised of a subset from the CDR pilot study that included children who had died from an RTC-related injury, and a subset from CSA data that included all children assessed by the trauma unit, RCCH for an RTC injury between 1 January and 31 December 2014. The inclusion of these two datasets was to provide a better understanding of the RTC mortality and morbidity burden experienced by children younger than of 13 years. RTC deaths are classified as unnatural and are categorised into mechanisms of injury namely pedestrian, motor vehicle accident (MVA), cyclist, and train. This thesis defined child road crash-related injury or death as the injury or death of a child either as a pedestrian, motor vehicle passenger, motorcyclist; or train passenger, with the responsibility for the death being determined through the medico-legal mortuary based on the Inquest Act of 1959 (Republic of South Africa, 1959), and the type of injury severity being determined by the attending clinician in the trauma unit.

Childsafe South Africa (CSA) only collects data for children 12 years and younger. To compare the data across the two datasets, the data was categorised with the same age groups. There were several cases removed from the CSA dataset, including: missing age (n=2, 0.2%), fatalities already included in the CDR dataset (n= 5, 0.4%), injured by a train (n= 3, 0.3%), and children injured outside of the SRM catchment area (n=385, 33.5 %).

Variables analysed in the study that came from both datasets included age, gender, mechanism of injury, place of incident, and anatomical location of the injury. Additionally, specific variables from each data source were analysed as well. The CDR data source included COD while the CSA dataset included severity of injury and hospital admission. The following mechanisms, pedestrian and passenger, were included as causes of fatal and non-fatal RTC injuries. To assess the injury severity of fatal and non-fatal injury, RCCHs implements the four-point Abbreviated Injury Score (AIS) which ranks and compares injuries by severity and uses standard terminology to describe injuries (Association for the Advancement of Automotive Medicine, 1998; Peden, 2008).

The data (CDR: SRM post-mortem reports; CSA: trauma unit records) were first transcribed onto each of the respective data collection forms, followed by capturing into Microsoft Excel. National estimates were derived from the National Injury Mortality Survey (2009) (Matzopoulos et al., 2015), and the data analysed using Stata version 12 (Stata Corp). Descriptive statistics for all categorical variables were analysed as a proportion. Age was only analysed as a categorical variable and was categorised for children as younger than one year, 1 to 4 years, 5 to 9 years, and 10 to 12 years (Isaac et al., 2015).

Morbidity due to RTCs was determined by estimating the YLD using the CSA dataset by following Haagsma's methodology (Haagsma et al., 2016). YLD incidence was used since all the cases used in the study were reported in the same year, i.e., 2014 (1).

$$YLD_{cas} = I_{cas} \times DW_{cas} \times L_{cas} \quad (1)$$

Where: I is the number of incident cases for a defined period, for a given cause (c) at a specific age (a) and gender (s); DW is the disability weight a given cause (c) at a specific age (a) and gender (s); and L is the duration of the condition (c) at a specific age (a) and gender (s).

Cases that had multiple injuries adhered to the nature-of-injury hierarchy created by Haagsma et al. (2016), whereby the nature-of-injury category leading to the largest long-term burden -- combination of likelihood of long-term disability with corresponding disability weight . Disability weighting (DW)s was allocated according to the hierarchy of nature of injury where for cases of multiple injuries, the highest DW assigned to a nature of injury for that case was selected. In addition, the DW was also then allocated depending on whether the child was an inpatient (referring to injury cases that have a severity requiring inpatient care with no restrictions to access to healthcare) or an outpatient (referring to injury cases that have a severity that does not require admission to a hospital) status (Haagsma et al., 2016). The duration of disability for each case was assigned based on the values reported by Haagsma et al. (2016) because there are no studies reporting duration of disability in South Africa.

A multinomial regression analysis was utilised to determine if the independent predictor, hospital admission to RCCH followed by a non-fatal RTC injury, was adjusted for age. Age

and gender are well known risk factors for injury and in this thesis, were controlled as a priori confounders. Odds ratios were calculated by using a 95% confidence interval and any result with $p < .05$ was considered significant for all analyses. To determine the statistical validity of the model, a Pearson goodness of fit test was used resulting in a $p = .30$; therefore, the model was acceptable for the analysis.

6.4 Data Sources

Two data sources were used for the analysis of this objective: FPS (SRM) specifically CDR, and Childsafe (CSA database, trauma unit, RCCH).

6.4.1 Childsafe

RCCH is a tertiary public paediatric hospital, which provides 24-hour casualty, surgical and sub-specialty services for children younger than 13 years, and serves its immediate environment including private and public institutions across CoCT (Isaac et al., 2015). Childsafe South Africa (CSA) is a non-governmental organisation which since 1991, has managed an electronic surveillance system for all injured children admitted to RCCHs trauma unit (Isaac et al., 2015). Childsafe was chosen because it is one of the few continuous and high quality sources of childhood injury data in South Africa (Isaac et al, 2015).

To compare the data across the two datasets, the data was categorised by age group. There were several cases removed from the CSA dataset, including: missing age ($n=2$, 0.2%); fatalities that were already in the CDR dataset ($n= 5$, 0.4%) ;injured by a train ($n= 3$, 0.3%); and children injured outside of the SRM catchment area ($n=385$, 33.5%).

To assess the severity of both fatal and non-fatal injuries, RCCHs implements the four-point Abbreviated Injury Score (AIS), which ranks and compares injuries by severity, and uses standard terminology to describe them (Association for the Advancement of Automotive Medicine, 1998 2008). Injuries are defined by body region, type of anatomical structure, specific anatomic structure, and the level of injury. The severity of injury can be classified as either mild, moderate, severe or mortal (Copes et al., 1988; Peden, 2008). When injuries are classified as mild, the patient only requires minor treatment and is discharged on the same day as presenting to the trauma unit. A patient with moderate injuries requires admission, as they have wounds that need suturing, fractures, or minor to intermediate head injuries. Patients with

severe injuries require resuscitation or admission into the intensive care unit; this includes all poly-traumatised patients, all shocked patients, and those with severe head injuries. (Isaac et al., 2015). Mortal cases involve fatal injuries.

After assessing the child, the attending medical professional from the trauma unit assigns the AIS, which is then reviewed by a senior clinician who finalises all diagnostic determinations (Isaac et al., 2015). Disposition indicates that a patient was either admitted to RCCH or was discharged from the trauma unit (Isaac et al., 2015).

6.5 Results

There were 37 fatal RTC injuries reported from the 2014 CDR dataset and 727 non-fatal RTC injuries cases from the CSA dataset. Table 6.2 shows the RTC child mortality rate from SRM for all children younger than 12 years, compared to the national estimates for 2014. Overall, the RTC fatality rate for this thesis was approximately 1.3 times lower (8.7 per 100 000 children aged 0 to 12 years) than the national estimate (11.7 per 100 000 children aged 0 to 14 years). Nationally children younger than 5 years old were the most affected (14.8 per 100 000 children younger than 5 years old), whereas children in the 5 to 9 years age group (8.4 per 100 000 children aged 5 to 9 years) were most affected in this thesis.

Table 6.2

Description of child RTC mortality rate (per 100 000 population), by age: CDR data (2014)

Overall Child Death Review (CDR) RTC mortality rate, Metro West, 2014		Overall child RTC-mortality rate, National estimates, 2009	
1-4 years	6.9	0-4 years	14.8
5-9 years	8.4	5-9 years	11.8
10-12 years	8.3	10-14 years	8.5
1-12 years	8.7	0-14 years	11.7

*2009 National estimates reported in the Injury Mortality Survey (2015) (Matzopoulos et al., 2015)

Figure 6.1

Figure 31. Premature mortality of RTCs as a percentage of years of life lost (YLL) across age groups, CDR pilot study, 2011-2015; Metro West, CoCT

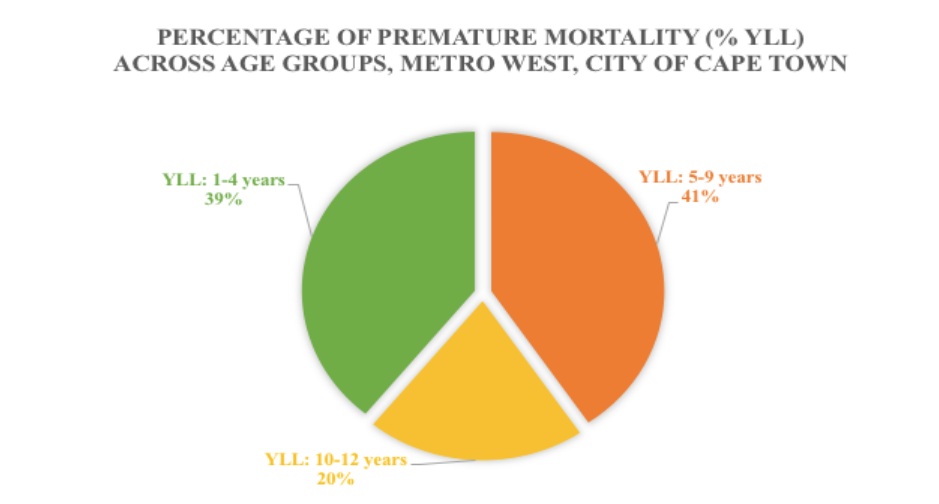


Figure 6.1 displays the contribution of RTC fatality relative to premature mortality. The RTC premature mortality for 2014 was similar for children aged 5 to 9 years old (41.0%) and those aged 1 to 4 years (38.0%), with children aged 10 to 12 years old only contributing 21.0%.

Table 6.3 presents demographic characteristics such as gender, age grouping, and transport mechanism for both fatal and non-fatal RTC injuries. No fatal injuries were found for infants (< 1 year old); however, all non-fatal injuries (n=17, 2.3%) were in infants younger than 1 year. Most children involved in an RTC incident were aged 5 to 9 years old with 40.5% (n=15) involved in a fatal RTC and 46.6% (n=360) in a non-fatal RTC. With respect to gender across all age groups, more males (n=458; 62.6%) than females (n=269; 36.8 %) ($p < .0001$) were involved in a non-fatal RTC injury. However, for fatal RTC incidents, there was no significant difference observed between males and females ($p = .101$). Pedestrians were found to be the leading mechanism of death in fatal RTC injuries (n=31; 83.8%) and non-fatal RTC injuries (n=554; 72.5%), with more males experiencing a fatal pedestrian injury ($p = .1$) or non-fatal pedestrian injury ($p = .001$) than females. However, there were more female passengers (n=84; 58.3%) involved in a non-fatal RTC injury than males (n=60; 41.6% across all age groups ($p = .04$)). The study found that across all age groups, when comparing the total fatal and non-fatal RTC injuries, males (62.8%; $p < .0001$) contributed to the greatest proportion of those who were involved in a pedestrian incident (63.8%; $p < .0001$).

Table 6.3

Characteristics of RTC injury, by age and gender Metro West, CoCT, South Africa, 2014

	CDR				Childsafe South Africa				Total			
Total RTC injuries												
	Male (n=22) %	Female (n=15) %	Total (n=37) %	P- value	Male (n=458) %	Female (n=269) %	Total (n=727) %	P- value	Male (n=480) %	Female (n=284) %	Total (n=764) %	P- value
< 1 year	-	-	-	-	2.2	2.6	2.3	0.74	2.2	2.6	2.3	0.74
1-4 years	40.9	33.3	37.8	0.64	34.9	39.8	36.6	0.19	35.2	39.4	36.8	0.24
5-9 years	31.8	53.3	40.5	0.19	48.2	44.2	46.6	0.3	47.5	44.7	46.4	0.45
10-12 years	27.2	13.3	21.6	0.31	14.2	13	14	0.65	14.8	13	14.1	0.49
Missing	-	-	-	-	0.4	0.4	0.6		-	-	-	-
All ages	59.4	40.5	100	0.1	62.6	36.8	0.6	0.0001	62.8	37.2	100	0.0001
Mechanism of RTC injury												
Pedestrian												

	n=19 (%)	n=12 (%)	n=31 (%)	P- value	n=335 (%)	n=188 (%)	n= 525 (%)	P- value	n=354 (%)	n=200 (%)	n=554 (%)	P- value
< 1 year	-	-	-	-	0.9	1.1	0.1	0.82	0.8	1	0.9	0.81
1-4 years	42.1	41.6	41.9	0.98	39.4	36.7	38.4	0.54	39.5	37	38.6	0.56
5-9 years	36.8	50	41.9	0.47	50.4	48.9	49.9	0.74	49.7	49	49.4	0.87
10-12 years	21.1	8.3	16.1	0.35	9.2	12.8	10.5	0.2	9.8	12.5	10.8	0.32
Missing	-	-	-	-	0	0.5	0.4	-	0.2	0.5	0.3	-
All ages	61.2	38.7	83.8	0.05	63.8	35.8	71.8	0.0001	63.8	36.1	72.5	0.0001
Passenger												
	n=3 (%)	n=3 (%)	n=6 (%)	P- value	n=84 (%)	n=60 (%)	n=144 (%)	P- value	n=87 (%)	n=63 (%)	n=150 (%)	P- value
< 1 year	-	-	-	-	8.3	6.6	9.7	0.7	8.04	6.3	7.3	0.68
1-4 years	33.3	-	16.7	0.28	28.6	46.6	38.8	0.029	28.7	44.4	35.3	0.05
5-9 years	-	66.7	33.3	0.08	41.6	36.6	42.5	0.54	40.2	38.1	42.1	0.79

10-12 years	66.7	33.3	50	0.27	21.4	10	10.4	0.05	22.9	11.1	12.1	0.05
Missing	-	-	-	-	-	-	-	-	-	-	3.2	-
All ages	50	50	16.2	1	58.3	41.6	19.8	0.04	42	58	19.6	0.006
Cyclist/Motorcyclist												
	n=0	n=0	n=0	P-value	n=36 (%)	n=19 (%)	n=55 (%)	P-value	n=36 (%)	n=19 (%)	n=55 (%)	P-value
< 1 year	-	-	-	-	-	-	-	-	-	-	-	-
1-4 years	-	-	-	-	11.1	52.6	25.4	0.0008	11.1	52.6	25.4	0.0008
5-9 years	-	-	-	-	44.4	21.1	45.7	0.088	44.4	21.1	36.4	0.088
10-12 years	-	-	-	-	38.8	26.3	23.9	0.35	38.8	26.3	34.5	0.35
Missing	-	-	-	-	-	-	0.3	-	-	-	0.3	-
All ages	-	-	-	-	65.4	34.5	7.6	0.0012	65.4	34.5	7.6	0.0011

The most dominant anatomical location of injuries across all ages was a head injury (37.8%) followed by multiple injuries (9.0%). This was observed in both fatal and non-fatal RTC cases (Figure 6.2). Pedestrians involved in non-fatal incidents with head injuries impacted children aged 1 to 4 years (36.6%) the most while multiple injuries were found to be highest in children aged 5 to 9 years (24.1%). However, for passengers, head and multiple injuries were observed to decrease with age.

Figure 6.2

Anatomical location of injury, by mechanism of injury and age category as a percentage; Metro West, CoCT, South Africa

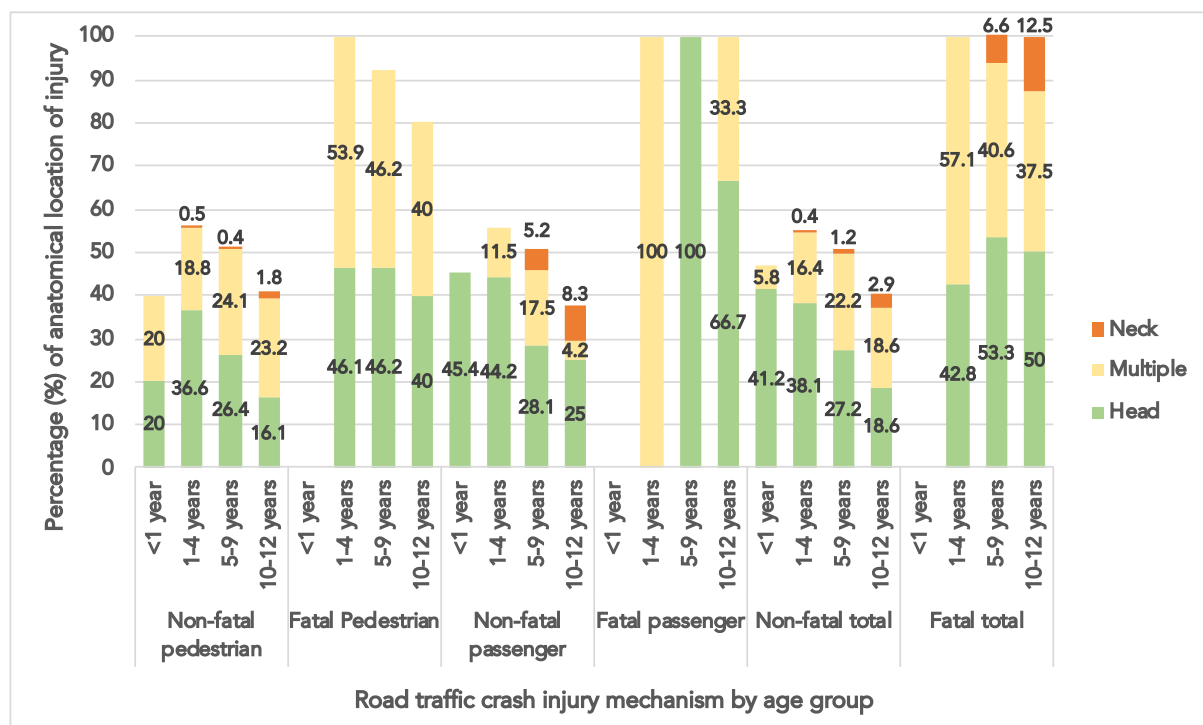


Table 6.4 represents the severity of non-fatal RTC injuries by using the AIS index. According to the study, moderate injuries were the most common type of injury among children involved in a non-fatal RTC (n=338; 49.1%), followed by minor injuries (n=315, 46%), and severe injuries (n=35, 5%). For children involved in non-fatal injury, only 34.8% (n=242) were admitted to RCCH of whom 79.3% suffered a moderate RTC-injury (n=192), followed by severe (n=26; 10.7%), and minor RTC-injuries (n=23; 9.5%) (Table 6.4).

Table 6.4

Injury severity and disposal of patients with non-fatal injuries, by age, Childsafe South Africa dataset, 2014

	< 1 year		1-4 years		5-9 years		10-12 years		Total	
	n=17	percent	n=268	percent	n=341	percent	n=102	percent	n=695	percent
Severity of injury (n=689)										
Minor	8	47.1	129	48.1	154	45.2	42	41.2	336	45.9
Moderate	8	47.1	123	45.9	169	49.7	52	50.9	352	48.2
Severe	1	5.8	11	4.1	16	4.6	8	7.8	36	4.9
(Missing)	-	-	5	1.8	1	0.2	-	-	6	0.8
Hospital Admission (n=249)										
Admitted	7	2.8	90	36.1	118	47.4	34	13.6	249	34.1

The YLD rate was determined across all age groups based on the mechanism of injury, nature of injury, and hospital admission (treated as an inpatient or outpatient) (Table 6.5). This thesis found that the rate of YLDs caused by RTC incidents for children younger than 12 years old receiving medical treatment at RCCH decreased with age. The YLD rate was highest for pedestrians (327.8 YLD per 100,000 aged children 5 to 9 years old), passengers (256.3 YLD per 100,000 children younger than 1 year), and cyclists (10.3 YLD per 100,000 children aged 10 to 12 years old). However, pedestrian incidents contributed the greatest proportion to the rate of YLDs compared to any other transport mechanism, with children aged 1 to 4 years old (259.9 per 100,000) and 5 to 9 years old (327.8 per 100,000) the most affected. Fractures were the most prevalent nature of injury, contributing the greatest proportion of the total YLD rate across all ages. The highest fractures were in children aged 5 to 9 years old (376.3 YLDs per 100,000), followed by children aged 1 to 4 year old (201.2 YLD per 100,000). Burns were the least prevalent nature of injury, accounting for 1.2 YLD per 100,000 children, and only impacted children aged 1 to 4 years old. Moderate/severe traumatic brain injuries greatly impacted children aged 1 to 4 years old and 5 to 9 years old, contributing to 81.0 and 84.4 YLD per 100,000 children, respectively.

Table 6.5

Description of YLD (YLD) rates for Metro West, CoCT, South Africa, 2014

	Mechanism of Injury	Pedestrian	Passenger	Cycle/ Motorcycle	Other	Nature of Injury	Burns	Fractures	Minor TBI	Moderate/ Severe TBI	Minor Injuries	Other Injuries	Patient disposal	Inpatient	Outpatient
YLD rate* 0-12 years		131.5	21.3	7.6	1.5		1.2	137.5	16.2	38.6	6.7	12.7		120.7	56.2
YLD rate* 10-12 years		57.5	17.6	10.3	0.8		-	82.8	2.2	19.9	4.6	4.9		29	64.3
YLD rate* 5-9 years		327.8	57.2	18.6	6.1		-	376.3	38	84.4	14.9	28		139.8	315
YLD rate* 1-4 years		259.9	27.3	9.6	-		6.9	201.2	42.2	81	142.3	33.3		108.3	207.8
YLD rate* <1 year		58.2	256.3	-	9.7		-	76.4	-	38.5	2.3	-		24.2	

*Per 100,000 population (age specific)

*TBI: Traumatic Brain Injury; Minor injuries: 'Other injuries of muscle and tendon and other dislocations', Foreign body in ear and GIT, open wounds, contusion and superficial injuries; Other injuries: Injury to eyes, Nerve injury, Severe chest injury

There were several risk factors assessed to determine the likelihood of admission to RCCHs trauma unit following a non-fatal RTC incident (Table 6.6). Non-fatal RTC incidents that occurred in the evening or afternoon, compared to the morning, were 1.99 times ($p < .01$) or 1.86 times ($p < .01$) more likely to result in admission to RCCH, respectively. Furthermore, incidents that occurred over the weekend, compared to during the week were 1.46 times ($p = .029$) more likely to result in admission to RCCH. Pedestrian in non-fatal incidents were 2.31 times more likely to be admitted to RCCH compared to pedestrians in any other RTC mechanism of injury ($p = .018$).

Table 6.6

Risk of non-fatal RTC injury by admittance to trauma unit at RCCH for children under 13 years, 2014

Admitted				
Variables	Crude OR (95percent CI)	p-Value	Adjusted OR (95percent CI)	p-Value
Age: (reference < 1 year)				
1-4 years	0.49 (0.16-1.51)	0.22	0.43 (0.13-1.41)	0.16
5-9 years	0.52 (0.17-1.57)	0.24	0.38 (0.089-1.56)	0.18
10 - 12 years	0.56 (0.18-1.82)	0.34	0.34 (0.052-2.19)	0.26
Gender : (reference male)				
Gender	1.21 (0.86-1.70)	0.26	1.21 (0.86-1.68)	0.28
Anatomical location: (reference Yes)				
Head injury	1.11 (0.78-1.58)	0.59	1.11 (0.78-1.58)	0.59
When incident occurred: (reference Week)				
Weekend	1.48 (1.04-2.08)	0.026	1.46 (0.48-0.95)	0.029
Time of day: (reference Morning)				
Afternoon	1.87 (1.21-2.91)	0.005	1.86 (1.20-2.91)	0.005

Evening	1.99 (1.29-3.08)	0.002	1.99 (1.29-3.08)	0.002
Pedestrian	2.25 (1.13-4.49)	0.02	2.31 (1.15-4.60)	0.018
Passenger	1.71 (0.80-3.65)	0.16	1.74 (0.81-3.72)	0.15

6.6 Discussion

This thesis shows that children aged 5 to 9 years old were the most affected compared to any other age group in either a fatal (40.5%) or non-fatal (46.6%) RTC incident. The pattern of fatal and non-fatal RTC incidents increased over time. Several factors that influenced the likelihood of either a fatal or non-fatal RTC incidence were identified.

6.6.1 Gender

This thesis found that male children were more likely to be involved in either a fatal or non-fatal RTC. It was found that 59.4% of children involved in a fatal RTC incident were male compared to 40.0% of females across all ages, although this gender difference was not statistically significant. This finding is in line with the 2014 RTC pattern for SSA, that reported a higher RTC mortality rate for male children than females (Institute for Health Metrics and Evaluation, 2021). Prinsloo et al. (2021) reported that in 2017, male children younger than 14 years in South Africa were 1.3 times more likely than female children to be involved in a fatal RTC incident (Prinsloo et al., 2021).

Risk-taking behaviour and parenting style influence the likelihood of males being more involved in an RTC incident than females. A study in the UK found males inherently take more risks than females as they are more adventurous, exploring their surroundings, particularly while playing, which can be attributed to social norms that define the behaviours of males and females. This potentially leads parents to supervise female children more closely than male children and differently socialise males by encouraging them to take more risks (Harré, 2000, Waylen and McKenna, 2008).

6.6.2 Age

Children aged 5 to 9 years old were the most at risk compared to any other age group in both fatal (40.5%) and non-fatal (46.6%) RTC incidents. The RTC mortality rate in this age group (8.4 per 100 000 children aged 5 to 9 years old) was 1.3 times higher compared to the global rate (6.2 per 100 000 children aged 5 to 9 years old) (Institute for Health Metrics and Evaluation, 2021). However, it was 1.3 times lower than the South African national estimate of 11.7 per 100 000 children aged 0 to 14 years old (Matzopoulos et al., 2009). The difference in the global RTC mortality rate compared to this thesis is expected since the national RTC mortality rate for children is higher than the global rate (Matzopoulos et al., 2015).

The CoCT is one of the most urbanised and populous metros in South Africa, with a high traffic density, which significantly contributes to the RTC rate. However, the difference reported in this thesis may be due to the relatively small sample size used, compared to nationwide studies; i.e., the results were from one mortuary; and included data from only four of the eight sub-districts located within the CoCT district.

Evidence indicates that age intersects with gender and influences risk-taking behaviour and overall RTC incidence. Premature mortality is influenced by incidence; in this thesis, the RTC premature mortality was higher in children aged 5 to 9 years old than in any other age group. This evidence suggests that children aged 5 to 9 years old are more vulnerable than younger children. Generally, young children (younger than 5 years) require more supervision than middle-aged children (older than 5 years) because in this development phase, they are still learning to communicate their needs and determining if their world is safe by observing interactions with others.. They are therefore more dependent on others for guidance when navigating their environment (Raising Children.Net.AU, 2020). As children age, they become more independent, exploring their environment by trying new things, and testing boundaries, like walking/playing near oncoming traffic (Raising Children.Net.AU, 2020a). This places these children at a greater risk of pedestrian RTC involved and increases potential loss of life. As children in this age group become more independent, with time spent at school requiring less supervision; they start taking risks and make independent decisions, like if it is safe to cross a road to avoid oncoming traffic (Harré, 2000, Waylen and McKenna, 2008).

6.6.3 Mechanism of Injury

In this thesis, pedestrians were found to have highest fatal (83.8%) and non-fatal RTC (71.8%) incidents, particularly children aged 5 to 9 years old. Findings from the South African National Injury Mortality Study in 2009 found that nearly a quarter (23.0%) of South African children younger than age of 13 years old were involved in a fatal RTC incident as pedestrians (Matzopoulos et al., 2015). The prevalence of pedestrian injury in children can be partly attributed to their small physical stature, making them difficult for the drivers to see. In addition, the RTC burden is also influenced by the physical environment of an area, specifically the design of roads and the community's SES. In poor urban communities, the physical environment is generally characterised by poor road infrastructure, a lack of raised sidewalks or road barriers, and safe spaces for children to play. This forces pedestrians to share the road with motor vehicle drivers, cyclists, and motorcyclists. Furthermore, when roads are narrow, unpaved, poorly lit, and vehicles drive at high speed, the conditions are ripe for an RTC (Derry et al., 2007; Mock et al., 1999).

6.6.4 Anatomical Location

This thesis found that children across all ages were more likely to sustain a head injury as a pedestrian resulting in either a fatal or non-fatal RTC incident. Head injuries are mainly caused by a frontal collision between a vehicle and a child (Chakravarthy et al., 2007). When a child is involved in an RTC as a pedestrian, their centre of gravity is below the bumper of a car and it is more likely to strike a their head, compared to an adult involved in a similar RTC (Chakravarthy et al., 2007). A young child's head is the heaviest part of the body thus causing it to collide first with the vehicle compared to the rest of the child's body, suggesting that physical stature (size), particularly in young children, is a major contributor to the RTC burden.. Additionally, the size of the vehicle influences the severity of the injury and likelihood of death (Roudsari et al., 2004), suggesting that vehicle design in combination with the size of the child further impacts the RTC burden. Furthermore, Yao et al. (2007).found that the severity of a pedestrian incident is dependent on the speed of the vehicle; for example, if a vehicle speed is at least 30 km/h, the risk of a child pedestrian sustaining a moderate head injury increases by 23.0%. A limitation of this thesis was the lack of data about the speed of the vehicle, , which is a factor in the risk of a child dying as a pedestrian.

6.6.5 Supervision

This thesis did not include data related to supervision of the child during the RTC incident because the existing data did not provide sufficient information about the child's care during the time of a RTC incident. However, supervision is thought to be a significant factor of the risk for any injury incident among children, including RTCs. Caregiver supervision is essential in preventing an RTC injury, particularly in young children. Data from the CDR show that the circumstances surrounding RTC deaths suggest that unsupervised or unattended children along the roadside increases their RTC risk, especially those younger than 5 years old (Mathews S, 2014). However, this thesis had a small sample size for this variable; therefore, it was not possible to determine the association between caregiver supervision or characteristics and fatal RTC cases. The CSA dataset does not collect this data for non-fatal RTC cases.

Most of school-going age children walk to school both in the morning and afternoon. Children involved in an RTC incident in the afternoon or evening were more likely to be admitted to hospital than those involved in the morning. However, in this thesis, most RTC cases in children admitted to hospital were more likely to occur over the weekend than during the week. This suggests that children were outside and unsupervised during the time of the child's RTC incident. Based on the results from this thesis, it is possible that when children walk to school in the morning, they are accompanied by a caregiver on their way to work, compared to the afternoon, when children walk home with their age mates and are not supervised by a caregiver, therefore increasing the likelihood of a pedestrian incident.

6.6.6 Policy Recommendation

To address the RTC burden in an effective manner, policies and related laws that promote road safety, in particular pedestrian safety, and target societal norms such as compliance with the laws of the road, need to be promoted. In addition, these policies and laws need to be effectively enforced. To prevent RTCs, South Africa has enforced/ legislated a range of traffic laws and policies.

6.6.7 Road Traffic Crash Policies

To protect vulnerable road users like children, South Africa has legislated policies and regulations that govern speeding within residential spaces, limiting alcohol consumption levels while driving, and influencing passenger and pedestrian behaviour.

South Africa has policy regarding speeding in urban areas especially near schools, and regulations that govern the behaviours of pedestrians, passengers, and drivers. The National Road Traffic Amendment Act 64 2008, includes:

For pedestrians, drivers, and passengers:

- Reducing the speed limit on urban roads in residential areas to 50 km/h

Specifically, for drivers and passengers:

- Reducing the driver alcohol limit to under 0.05 mg/dl
- Requiring the use of child seat restraints for children
- Requiring the use of helmets when riding a motorcycle or bicycle

Human behaviour accounts for 75 to 90% of road trauma. It includes aggressive driver behaviour; distracted drivers, such as using a cellphone or consuming a beverage while driving; excessive speeding; and the lack of enforcement of road traffic rules (Arrive Alive, 2012). However, enforcement of these rules and regulations is limited and hampers its success. Countries that have championed the reduction of RTC trauma, such as Sweden, experienced a decrease of RTC mortality of 1.2 per 100,000 children younger than 15 years old in 2017, compared to 3.9 deaths in 1995 when the Vision Zero' strategy was implemented. This strategy focused on improving road infrastructure instead of individual behaviour such as speeding, drinking alcohol, and driving.

South Africa has implemented its national road safety strategy 2016-2030, which aims to create a safer road network by adopting a safe system approach similar to Sweden's Vision Zero strategy. This strategy achieved near-zero fatal or serious RTC injuries on the road by having a core principle of "no loss of life is acceptable" (Department of Transport, 2017). This Vision Zero strategy aligns with South Africa's 2030 National Development Plan to reduce RTC fatalities by 50% by 2030. However, the significant challenge for reducing this burden across South Africa is the limited systematic implementation of road safety policies and initiatives (Wallis, 2011).

6.6.8 Road Traffic Crash Interventions

The Haddon Matrix (Conroy & Fowler, 2000) is a widely used evaluation tool providing a framework to highlight risk factors and interventions for injury prevention. Still, its usefulness is based on the availability of injury-related data and limitations inherent in data sources. The availability of injury-related data is limited and underreported, with incomplete data sources (hospitals, mortuaries, police, transport, etc.). This is prevalent in upper middle-income countries and LMICs, where protocols and parameters of how this data is reported and utilised differ. In South Africa, one of the most supported campaigns is Arrive Alive. It promotes road safety awareness by disseminating road traffic reports nationwide, safety tips for drivers, vehicle compliance, having different enforcement agencies involved in road safety, and advice by multiple experts (Arrive Alive, 2022). Interventions discussed below pertain to findings from this thesis utilising the Haddon-Matrix framework.

6.6.9 Pre-event

Even before a child is involved in an RTC incident, they are already at a disadvantage particularly because of their age. This thesis found children aged 5-9 years most vulnerable. Injury preventative programmes in HICs that are integrated across sectors are prioritised, while in the past LMICs with support by WHO and UNICEF prioritised the prevention of childhood infectious diseases such as low respiratory tract infections and the active participation of the expanded programme of immunisations (EPI); have now also included injury prevention with a focus on RTC. In HICs, these programmes involve adapting road infrastructure to be more pedestrian and child friendly in residential areas and increasing the implementation and enforcement of child restraints which have greatly contributed to a decline in RTC passenger deaths in young children (Quinlan et al., 2000; Schlotthauer et al., 2011). One of South Africa's child centred nationwide RTC preventative strategies; the Learner Transport policy aims to ensure that scholars are provided with safe transport to school and back home. However, there are several flaws to the policy that make it inaccessible to all children. The policy prioritises rural areas over urban areas with children residing in urban areas walking to school for more than an hour also prioritised (STATSSA, 2014). Several provincial governments created their own transport policies adapted from the National Transport Policy. For example, the Western Cape provides learner transport services to suburbs if at least 10 scholars require transport, however, children from sparsely populated suburbs will miss out. Similarly, if public transport

is available in these suburbs, scholar transport will not be provided without considering if the child can afford public transport with the exception of Grade-R learners (TCT, 2017).

Investing in safe public transport services provided by the government is cost-effective. For example, the taxi (Akpa et al.) industry is the most widely used mode of transport in South Africa's transport system with more than 200,000 taxis on the road generating nearly R40 billion per year (STATSSA, 2017a). However, taxis are an unsafe mode of transport for children because there is no vetting process of taxi drivers. Taxi drivers are known for unsafe driving behaviour, and placing children at risk of possible sexual assault by taxi drivers and network. Thus, to make this mode of transport safe for children, the nature of the public transport system as a whole need to change.

Most children in South Africa, particularly in the Western Cape Province (WC), involved in a RTC incident continue to be pedestrians. To prevent and reduce pedestrian incidents in the WC several initiatives are implemented and are funded by public-private partnerships: namely the "Chevron Visibility Program" and the "Safe Travel to School Programme". The latter is a collaboration between Discovery Insure and CSA which focuses on improving scholar transporters driving behaviour and road safety awareness when transporting school children. Since its implementation in 2014, the "Safe Travel to School Programme" has had 800 drivers with 10,000 learners being transported from home to school within the CoCT (Mlamla, 2018).

In addition to child factors, there are other factors prior to a RTC incident; namely speed, lack of enforcement of alcohol laws, and conviction following a transgression against these laws that influences the severity of injury and likelihood of death.

6.6.10 Speed

Speed is a major contributor to pedestrian injuries; however, it was not possible to collect speeding data for this thesis. According to the WHO, countries that have implemented RTC preventative programmes that include managing speed limits between 30-80 km/hr in areas with high RTC incidents (World Health Organization, 2018) have demonstrated a decline in the RTC burden. Motor vehicle speed influences the severity of a RTC injury. For example, a vehicle travelling at 80 km/h that knocks an adult pedestrian increases the risk of death by 100

%). A vehicle driving at 30 km/h increases pedestrian survival by 90 %. Because of their size, children would be at an even greater risk for both severe injury and death (World Health Organization, 2004). Thus, child-centred traffic calming measures need to be prioritised by implementing speed bumps, widening, and raising sidewalks for pedestrians to be separated from oncoming traffic; and restricting traffic volume in residential areas (Committee on Injury, 2009; World Health Organization, 2012). In 2006, London implemented a 20mph (32km/hr) speed limit in residential areas, which reduced child pedestrian incidents by 46.2 % (Grundy et al., 2009). The city of Durban introduced speed bumps around schools which demonstrated the improvement of pedestrian safety by reducing the pedestrian-vehicle collisions to 23 % (Nadesan-Reddy & Knight, 2013).

Regionally, the Western Cape Department of Transport and Public Works (WCDoTPW) has many initiatives targeted at reducing child pedestrian trauma namely “#SeeAndBeSeen” and “Safe Roads, Safe Kids” that aim to teach children the rules of the road and inform drivers of the importance of reducing their motor vehicle speed especially when children are around.

6.6.11 Alcohol

In South Africa, alcohol is an important risk factor for the RTC burden, accounting for nearly 48.6 % of these incidents (Prinsloo et al., 2021). Being under the influence of alcohol while driving increases the likelihood of a RTC more so if the driver has an alcohol level of more than 0.05 mg/dl. Some countries have found that when the legal alcohol drinking age was aligned with the age at which new drivers could obtain their driver’s licence, the passenger incidence declined. In 2018, the WCDoTPW road safety priority shifted from pedestrian injury prevention to the reduction of passenger deaths and created a costly television campaign focused on seat belt compliance known as the “First Kiss” and “#BoozeFreeRoads”. The latter campaign also focused on pedestrian fatalities.

Both campaigns targeted individuals who consumed alcohol and were intoxicated when walking on the road or as drivers; but are not directly targeted at the most vulnerable road users, i.e., young child pedestrians. However, Banstola and Mytton found that when breathalyser campaigns were implemented in combination with drinking and driving legislation, enforcement in urban and rural areas was cost-effective in preventing RTC incidents in countries of sub-Saharan Africa (SSA) and Asia (Banstola & Mytton, 2017). Unfortunately,

many of these initiatives lack a coherent national implementation strategy and coordination with provinces.

6.6.12 During Event

When an RTC incident occurs factors such as the use of child restraints and speed of the vehicle influence RTC severity and likelihood of death. The higher the speed of a vehicle, the less likely the driver will be able to slow down fast enough to prevent a collision with another vehicle, physical structure, or human being from occurring. To prevent passengers from sustaining severe injury or death if the vehicle is driven at excessive speeds, passengers should wear a seatbelt (Delavary Foroutaghe et al., 2020; Slyunkina et al., 2013; World Health Organization, 2018) and young children placed in car seat restrained in the appropriate manner. In countries where child restraint laws were implemented and enforced, the RTC morbidity rate for children declined by 82 % (Zaloshnja et al., 2007) and the RTC mortality by 28 % (Elliott et al., 2006). However, child restraint laws are more common in HICs than LMICs. South Africa passed its legislation on child restraint in 2014. However, since the child restraint law was passed the proportion of passenger fatalities for children under five years remained unchanged at five % between 2015 and 2019 with the lowest proportion of fatalities occurring in 2017 at 3.8 % (Road Traffic Management Corporation, 2015, 2017, 2019).

6.6.13 Post Event

Once a RTC incident has occurred, several factors such as adequate post-crash care and access to appropriate healthcare influence long-term outcomes. Based on the available data from this thesis, it is unclear if emergency services responded in a timely manner to provide care at the scene for individuals that died at the scene following a RTC incident. This thesis found that most children experiencing a non-fatal RTC suffered a fracture or moderate/severe TBI. However, children experiencing a non-fatal RTC incident had access to tertiary trauma care, thus reducing the injury severity.

6.7 Strengths and Limitations

This thesis only included the Metro-West region of the CoCT and RTC incidence is possibly lower compared to the overall City. Furthermore, this thesis only provided RTC mortality estimates for children aged 0-12 years compared to national estimates of the 0-14 year age group; therefore, it is not directly comparable. However, to have an accurate estimate of the

RTC burden for the city compared to national estimates, all sub-health districts and age groups (0-17 years) need to be included.

The small sample size of our CDR dataset could have contributed to the non-significant findings between male and females. The CDR dataset and Childsafe dataset were included in the study to provide a more insightful understanding of the RTC mortality and morbidity burden in children under the age of 13 years. Mortality data from post-mortem reports were used in the study. This type of data can provide an accurate and reliable source of information for trauma surveillance. Collection of vital registration data in many LMICs is limited as a result of poor coverage and completeness of death notification data. The completeness of vital registration data in South Africa varies by age group; in 2011 there were nearly 93.0 % of deaths under 15 years but only 53.0 % of deaths under one was completed ((Dorrington et al., 2014). Completeness of vital registration data can ensure that there is accurate injury death information available of children to develop preventative initiatives. The Road Traffic Management Corporation annually collects information on RTC risk factors in South Africa; human factors continue to contribute the most to RTC incidence in 2018 (89.3 %) such jay-walking – crossing a road unlawfully -- as a pedestrian (33 %), hit and run (14 %), and speeding (10 %) (Road Traffic Management Corporation, 2018).

The National Injury Mortality Surveillance System varies as the coverage decreased in recent years and there is a bias towards urban sites. LMICs have limited injury data as hospitals, and trauma data collection systems required to monitor the RTC burden are inadequate or unavailable (World Health Organization, 2015a). The systematic collection of emergency and trauma data needs to be strengthened and hospital-based morbidity surveillance systems should be incorporated to determine the RTC burden accurately. However, many resource constrained countries do not prioritise improving injury surveillance systems due to budgetary constraints (Kobusingye & Lett, 2000).

Child RTC mortality data in the study was only included from the Metro-West as SRM only services sub-health districts included within the Western part of the CoCT but the potential exists for this to be incorporated into standard injury surveillance systems across the city. In addition, non-fatal RTC injury data analysed only included information from the only specialist paediatric facility in the city which has an active injury surveillance system and excluded data

from private health facilities as well as other state hospitals across the district. All injury-related deaths are sent to a state mortuary such as SRM for an autopsy. The need for hospital-based trauma registries is evident as it allows for the tracking of various burdens of disease, especially injuries, thus making it possible to measure the effectiveness of interventions in trauma care (Clark & Hahn, 1999). South Africa has limited trauma surveillance capabilities nationally; however, only CSA collects longitudinal child injury data (Van As & Rode, 2006); therefore, monitoring and assessing child injuries such as RTC at a local level is possible.

Childsafe South Africa (CSA) data has a dual coding system with “nature” and “cause” of injury variables being coded separately. Therefore, YLD calculations were calculated with ease. However, this thesis reported YLD incidence and not YLD prevalence because “duration of injury” data was unavailable. Thus, DALYs were not possible to calculate. The study utilised the methodology proposed by Haagsma and colleagues to weigh the nature of injury to determine YLD incidence rate. To determine the YLD incidence rate, an injury hierarchy was created as a relationship between the cause of injury variable and nature of injury for each individual. If an individual suffered multiple injuries, the nature of injury that accounted for the largest estimated disability weighting was selected (Haagsma et al., 2016). Thus, injuries with a smaller disability weighting sustained by an individual could possibly have shifted estimates from medium to severe injury.

6.8 Conclusion

This thesis highlights the vulnerability of child pedestrians, especially males aged 5-9 years, who were at a greater risk of experiencing either a non-fatal or fatal RTC injury than children of any other age. Thus, interventions should be targeted at pre-adolescent male children and their caregivers. Even though caregivers play a crucial role in keeping young children safe from traffic on the road, it is not always possible given the poor socio-economic circumstances of these families. Therefore, the state must prioritise the broader injury prevention strategy and take responsibility for providing services and resources that create an enabling environment and safe spaces for children. On the other hand, older children who are more independent need to be aware of the road's dangers and take fewer risks when they approach a road. Caregivers should also play an active role in preventing RTC incidents, especially for young children. Practically, teaching young children the traffic rules and regulations and the importance of road safety increases the potential to reduce risky pedestrian behaviour when these children become

older. To tackle this burden head on in South Africa, RTC preventative strategies should be evidence-based and effectively resourced, specifically in areas with the greatest risk. These preventative strategies should include promoting child safety on the road in schools. Improved enforcement of the rules of the road, changing societal including road safety norms by converting suburbs, especially townships, to pedestrian right of way and creating a more equitable society; one where children living in poorer communities can play outside without the threat of being involved in a RTC incident. The systematic collection of emergency and trauma data needs to be strengthened and hospital-based morbidity surveillance systems incorporated to determine the RTC burden accurately.

Chapter 7: CONCLUSION AND RECOMMENDATIONS

This is the first study in South Africa and CoCT to utilise a spatial conceptual framework to explore childhood injury mortality, specifically for the transport burden, by incorporating spatial analysis. The determinants in this thesis covered not only demographic factors like age and gender, but also economic factors like deprivation and other factors like the number of lanes of a road. This thesis found that Klipfontein sub-health district, specifically in Nyanga, had the greatest burden of child injury death which was driven by homicidal stabbing amongst adolescent males (15 to 17 year old). Drawing on the principles of spatial epidemiology, this thesis shows that as a densely populated informal settlement, Nyanga is at greatest risk of childhood injury deaths. This finding is shown to be partly due to severe deprivation linked to poverty and structural inequalities that underpin the lack of resources and increase violence and safety in the community. Road traffic crashes (RTC) were the second leading COD among children and were the focus of this PhD study.

RTCs are the leading cause of injury globally and in South Africa. This thesis found that it impacted children across all age groups, but the risk decreased as children aged. Most RTC incidents were found to occur over the weekend, especially on Saturdays when children were at home and in the care of parents or caregivers. In this thesis the child injury burden (children aged 17 years and younger) was retrospectively assessed for the years 2011 to 2015. The injury profile of children was examined by using mortuary data from Salt River Medico-legal Mortuary (SRM) across four sub-health districts of the CoCT namely Klipfontein, Mitchells Plain, Southern, and Western. In addition, Childsafe data was used to determine the morbidity profile for children younger than 13 years, which can be used for modelling purposes to predict RTC morbidity.

7.1 Contribution to Knowledge

7.1.1 Objective 1

The first objective was to describe the injury epidemiology for children aged 17 years and younger from 2011 to 2015 and generate a heat map highlighting the density of the leading apparent manner of death across the study area.

This thesis found that 51.2% of child injury deaths were unintentional (across all age groups). The greatest driver of the fatal child injury burden was homicide followed by RTC. This finding

is similar to the global injury pattern for children reported in 2019, as well as the pattern for UMICs (Institute for Health Metrics and Evaluation, 2021). National estimates using mortuary data for 2017 in South Africa also found that unintentional injuries such as RTCs in children contributed more to the injury burden than intentional injuries (Prinsloo et al., 2021). This thesis reported similar trends to the national childhood injury patterns estimates. As such, there is a need to develop more effective injury prevention strategies, with a particular emphasis on homicides and RTCs. This requires different approaches and must be contextually relevant.

Older male children (aged 15 to 17 years) mostly died due to homicide, especially from sharp force injuries. This suggests that this MOD could be driven by behaviour, with gendered social norms that promote use of violence to resolve conflict already prevalent among adolescents. Therefore, interventions to prevent interpersonal male conflict should target younger age boys in their formative years to shift this pattern of behaviour (Van der Merwe, 2013). Homicide was also found to be the greatest contributor to premature mortality (YLL) among children. This is different for both UMICs, and LMICs (Institute for Health Metrics and Evaluation, 2021) as well as the national pattern in South Africa (Prinsloo et al., 2021, Matzopoulos et al., 2015). The availability of resources and awareness to prevent homicide fatalities was found to be location-dependent, with the least deprived suburbs reporting fewer injury fatalities. This could be due to the fact that these suburbs have the resources allocated to prevent homicides, such as a large number of police stations which increase visible policing.

This is the first study to report that most child injury deaths were reported in the Klipfontein sub-health district, with Nyanga being the most affected, and homicides the most likely form of injury death among children. This suburb has one of the highest unemployment rates and lowest household incomes, both of which are risk factors for increased homicide incidence, especially among the most vulnerable like children (Smit, 2020). Klipfontein is reported as having the highest concentration of informal dwellings, with approximately 380,000 individuals living in the sub-district with limited safe spaces (Smit, 2020). Compared to formal areas, most informal areas are unsafe, leading to greater likelihood for injury death. The suburbs with the highest population density represented the highest injury mortality rate across age groups, indicating the role of population density in injury mortality incidence.

This thesis found that the injury mortality pattern for children differed for young children. Children younger than five years mostly died due to fire-related incidents. Historically, most burn-related injuries experienced by victims admitted to RCCH are as a result of hot liquids like boiling water and are experienced by children younger than two years (Parbhoo et al., 2010). Over the past decade, the CoCT has seen a dramatic increase in shack fires, driven by an increase in the number of dwellings in informal settlements; dry windy conditions that increase the chances of runaway fires; open flame cooking; and illegal electrical connections (Walls & Zweig, 2017). This thesis found that most fire-related deaths were fire burns, with a smaller proportion dying from hot water burns. This suggests that these deaths were directly linked to the housing environment of impoverished areas in the city that lack formal housing. These homes lack suitable fire-resistant infrastructure and are unsafe for the residents, especially children. South Africa has one of the largest subsidised housing programmes in the world (Brown-Luthango et al., 2017). The state must provide shelter independent of and in addition to its obligation to take reasonable legislative and other measures in terms of the constitution to protect children. Additionally, it is the state's responsibility to provide shelter to children irrespective of resource availability (art. 28(1)(c)) (Caron et al., 2003). However, the question remains; if parents cannot fulfil their children's rights due to poverty, and children are subjected to unsafe living conditions, where does the responsibility lie to protect their rights?

7.1.2 Objective 2

The second objective was to describe the spatio-temporal pattern of transport-related fatality from 2011 to 2015; followed by a cluster analysis using a discrete Poisson model; and finally utilising a negative binomial (NB) model to determine the relationship of various demographic and socio-economic risk factors on transport-related injury fatality.

This thesis found that most transport-related deaths occurred during daytime across all age groups. However, the majority of these deaths occurred during peak traffic hours, specifically after 5 p.m. These deaths mostly occurred on a Thursday or on a Saturday. Peak traffic in CoCT during the weekday occurs between 5 p.m. and 6 p.m, suggesting that during these times, most caregivers are on their way home, and their children are unsupervised and hence not safe.

Utilising a heat map, cluster, and spatial regression analysis, this thesis found that Nyanga, the most deprived township, had the most transport-related injuries. This implies that, areas with high levels of deprivation, such as low employment levels, poor schooling infrastructure, lack of housing, and over-crowding, are more likely to have higher levels of transport-related mortality among children aged 0 to 17 years. Additionally, using an NB model, the study found being male, younger than 14 years and living in a deprived suburb was a strong predictor of transport-related mortality when taking into account speed limit and if there was more than one lane on the road. According to Noble et al. (2013), based on data from the 2011 Census, the least deprived province in South Africa was Western Cape Province. However, one of the most deprived sub-health districts, Klipfontein, with Nyanga suburb, has the highest homicide rate in South Africa. This shows that despite the Western Cape not being the poorest province, it has some of the most deprived districts, which could increase injuries especially among the vulnerable like children. Therefore, resource allocation for injury prevention should be more granular and investment into these interventions should consider other factors like population density by age group.

Evidence from this thesis suggests a need to strengthen infrastructure to prevent transport-related deaths especially in the most deprived suburbs with limited resources. According to Bulbulia et al. (2020), children aged 5 to 9 years were more at risk of dying as pedestrians, particularly in the most deprived areas in Johannesburg, because of inadequate road infrastructure like raised sidewalks. Children from deprived suburbs are more likely to walk to school or to access essential services like health; however, with the lack of adequate infrastructure like a bridge to walk over a busy highway, these children are at a greater risk of being involved in an RTC (Green et al., 2011; Ribbens et al., 2008).

7.1.3 Objective 3

The third objective was to analyse both child morbidity and child mortality from RTC injury in 2014, to gain an overall perspective of this burden.

Children aged 5 to 9 years contributed to the highest RTC premature mortality rate in 2014. Similarly, compared to other age groups, non-fatal RTC incidents are more likely to occur among children aged 5 to 9 years. Children in this age group become more independent and require less supervision when at school. Therefore, RTC risk is associated with innate factors

such as the developmental phase of the child, coupled with the social context in which children are raised. Children in this age group also start taking more risks and make independent decisions, like if it is safe to cross a road to avoid oncoming traffic without supervision and guidance (Harré, 2000, Waylen & McKenna, 2008).

Compared to females, males are more likely to be involved in a fatal or non-fatal pedestrian RTC incident. Pedestrian injuries mostly occurred in children aged 5 to 9 years compared to any other age group, with a similar trend in YLDs. According to the AIS, most children involved in a non-fatal RTC incident suffered from moderate injuries. The severity of a pedestrian incident has been found to be dependent on the speed of the vehicle; for example, if a vehicle speed is at least 30 km/h, the risk of a child pedestrian sustaining a moderate head injury increases by 23.0% (Yao et al., 2007). Therefore, if most children in this thesis sustained head injuries as pedestrians, it is likely that majority of vehicles were travelling at speeds greater than 30km/h. This would suggest that not only children's behaviour but also speeding of vehicles have contributed to RTC.

Hospital admittance as a result of a non-fatal RTC incident was mainly reported in children aged 5 to 9 years and was more likely to occur during afternoons or evenings over the weekend. This suggests that children, especially of school-going age, were outside and unsupervised in the afternoon or evening, increasing their risk of being involved in an RTC incident. Children are more likely to be accompanied by an adult or an older child in the morning on their way to school. There is an urgent need to address pedestrian RTCs which can be done by having safer means of transport and having adult supervision of children, therefore reducing the likelihood of RTCs. Additionally, children in this age group have limited knowledge of road safety principles; therefore, having road safety promotion initiatives targeting children as they start school is critical in ensuring that they understand these principles and integrate them in their behaviour on the road to enhance their safety.

7.2 Strengths

This thesis used various GIS methods to highlight the magnitude of the injury burden across the CoCT, by sub-health district. These methods included a choropleth map, heat map, point density map, discrete Poisson model, and negative binomial regression model. These methods visualised the injury burden across the CoCT and its sub-health districts, and highlighted the

injury burden for children in a novel way. This PhD study showcased the tools' utility to visualise where injury fatalities had occurred, for policymakers to target interventions to reduce RTC among children. The choropleth map highlighted the variation in MOD by age in the CoCT to provide some insight about which sub-health districts was most at risk of injuries. This was followed by a point injury map showcasing the distribution of injuries. Finally, by using a heat map, it was possible to locate sub-health districts that had the densest injury clusters. However, descriptive visualisation methods only allow policy makers to see what the injury burden looks like but do not provide information about the influence of socioeconomic risk factors, like the deprivation level of a suburb and the risk of injury burden. A discrete Poisson model aimed to showcase which transport-related injury clusters over space and time influenced the likelihood of these deaths in specific locations. The NB model was used to evaluate the relationship between demographic variables like age group, and socioeconomic variables like deprivation level, on transport-related injury. By using these methods, it was possible to link the most deprived suburbs to transport-related hotspots, which can be easily integrated into current injury surveillance systems. The most deprived suburbs (signifying a level of poverty) also had the most injury incidents over the 5 year period (2011 to 2015). This provided insight into the association of poverty, an aspect of deprivation injury experienced by children of all ages.

This thesis focused on the childhood injury pattern, as a child-centred analysis is often absent, limiting the utility of findings for children. Historically, the CoCT focuses on homicides in young adolescent males thus injury preventative initiatives only target homicides, particularly for this age group. Therefore, this thesis highlights the importance of focusing on childhood injuries across the life course and not only at one age group.

7.3 Limitations

This section provides a summation of the limitations of each study design that contributed to this PhD.

7.3.1 Data Sources

This thesis only used secondary data sources and therefore had no control of the variables collected by the various data sets. This influenced the variables available for use in the study, therefore affecting the reliability of the outcomes of the study. However, secondary data

analysis was useful for identifying gaps and ways of improving the routine data sources by advocating for the inclusion of certain variables in the datasets based on the data analysis for this PhD study. The primary data source for RTCs lacked details about alcohol use, supervision, or driver speed. Geographical variables such as public lighting on roads and double lanes, were limited or missing. Data from emergency services such as paramedics were also missing. Several RTC deaths were hospital-based and were excluded from the analysis because the dataset did not capture where the incident occurred. Incident data is important in highlighting which locations are at the greatest risk compared to others. Therefore, it is necessary to integrate various data systems like FPS, emergency medical services, SAPS, and traffic-related data. By integrating these data systems, it is possible to determine where the injury incident took place relative to the outcome in a timely manner. An integrated data system will provide insightful information about all forms of injuries, in particular less severe cases that did not require hospital admission but just an emergency room visit.

7.3.2 Incident Location

The primary data source utilising mortality came from SRM, which only covers the Metro West area of Cape Town, including Klipfontein, Mitchells Plain, Southern, and Western sub-health districts. This thesis showed the benefit of doing this type of analysis, especially at the city and provincial level, which helped identify areas requiring interventions to reduce child injury burden.

7.3.3 Data Quality

Poor data quality and missing data influenced the analysis of this PhD study. It is important that routine data sources improve the quality of data to ensure a reduction in missing, data and to include critical variables to comprehensively assess the role of injury risk factors. Such variables would include alcohol level of drivers, child supervision during death, and vehicle speed. Some cases lacked information on gender and GPS location, which were essential for the analysis of this thesis. Cases outside this thesis's area of interest were present in the current dataset and had to be removed because RCCH is a specialist hospital and only treats the most complicated cases. Therefore, the hospital admission data could be skewed to more severe or complicated injury cases that required specialist care. For boundary data to join this thesis's case data, there had to be an exact match of the small area code included in both datasets. Boundary datasets and health datasets have different geographical identifiers since they are

created by different departments with different objectives. To ensure that both datasets had the same geographical identifiers, the health data set was manually added based on the GPS of each incident. However, this information was missing for public lighting and dual lanes. Public lighting on the road would have provided insights into the time of death for RTC deaths. If there was limited lighting on the road, this could have influenced the pedestrian incidence since less lighting would make it harder for drivers to see the pedestrians.

7.3.4 Sample Size

Routine data from FPS was used in this thesis and with the assistance of the Health Impact Assessment unit of the Western Cape Provincial Health Department, the quality of the data was improved. However, to determine the RTC mortality burden, a sub-set of the data was used to procure a small sample size with the data points that were used for the spatial analysis chapter (pages 80-105). The RTC burden is one of the greatest factors influencing the wellbeing of children in South Africa; therefore, more studies to determine the factors influencing its incidence need to be carried out. The RTC chapter contained limitations from the CDR and Childsafe datasets. For Childsafe, the limitation was age since this dataset only collects data from children aged 0 to 12 years; as such, it was not feasible to compare the study to national estimates. The spatial analysis of the transport-related child injury mortality chapter was limited by the accuracy of the provided GPS locations for each death, and the SAIMD data, whose lowest geographical level was at the ward level. These limitations significantly reduced the sample size and hence influenced the analysis performed for each of these chapters. The CDR dataset was limited by the availability of supervision data, which was only recorded for a small number of injuries, particularly RTC incidents. This variable was an important risk factor to associate with the role of the caregiver in the prevention of RTC injuries.

7.4 Recommendations

Based on the findings of this thesis, a reliable and timely injury surveillance system integrating various data sources is required. This will ensure that appropriate and time-sensitive interventions are developed and implemented to prevent childhood injury mortality and disability across the CoCT. Evidence from this PhD study suggests that preventative childhood injury initiatives should prioritise promoting road safety education to young children in their school environment and to their caregivers. Additionally, there is a need for an injury surveillance system that includes more sources in addition to routine data, as this would provide

a holistic view of the child injury burden. These initiatives should be implemented in high-risk locations in large metros to prioritise the most vulnerable child populations. Furthermore, these interventions need to be child-centred to ensure that children's needs are met and are appropriate relative to the child's developmental age. For these initiatives to be sustainable, it is necessary to engage with communities, academia, and public-private partnerships to prevent injuries among children, especially those living in low socio-economic areas.

- There is need to develop a reliable and timely injury surveillance system that is comprehensive and live. Childhood injury surveillance systems developed as injury preventative initiatives have shown that having accurate and timely injury data enables the implementation of targeted injury initiatives that decrease the likelihood of injuries (Espitia-Hardeman et al., 2011; Linnan et al., 2011; Magnus et al., 2021). Evidence-based injury-preventative initiatives, designed and implemented in Pasto, Colombia by utilising injury surveillance data, focused on the prevention of fire-related injuries using a public campaign highlighting the dangers of fireworks, and prevention of RTCs (Espitia-Hardeman et al., 2011). These initiatives implemented drunk driving checkpoints in risky areas, and road safety education starting from preschool to all education levels. These initiatives contributed to a reduction of 37% of RTC deaths among children over a three-year period (Espitia-Hardeman et al., 2011).
- Injury-preventative initiatives like increased visible policing, lighting in public spaces, and safe spaces, are focused on high-risk locations and are age-appropriate with a focus on vulnerable populations (Andrade et al., 2021; Shabanikiya et al., 2020). In Medellin, Colombia; locations with focused initiatives like an increase in police patrols, lighting in public spaces, and more recreational spaces, demonstrated a decline in homicide fatality. Over time the positive effects of these place-based interventions have spilled over to neighbouring locations, hence reducing homicide fatalities in these areas as well (Cerdá et al., 2012).
- RTC preventative strategies should be evidence-based and effectively resourced, specifically in areas with the greatest risk. These preventative strategies should include promoting child safety on the roads near schools; improved enforcement of road rules; changing societal road safety norms by converting suburbs, especially townships, to

pedestrian right of way,, and creating a more equitable society (Malin et al., 2020; Shabanikiya et al., 2020; Shin et al., 2011). These areas are one where children living in poorer communities can play outside without the threat of being involved in an injury incident (Shabanikiya et al., 2020 2020; Shin et al., 2011).

7.5 Concluding Remarks

Injuries are one of the leading causes of mortality and morbidity among children living in the CoCT, South Africa. This thesis provided insights to identify high-risk child populations, by highlighting factors like the level of deprivation of the suburb, and the speed limit of the road. These factors are excluded in other studies determining which areas increase the likelihood of an injury from occurring by implementing a spatial conceptual framework. This research showed that children of a certain age are more vulnerable than others, especially males living in low socio-economic areas. Therefore, there is an urgent need for more sustainable and representative national injury surveillance to be integrated with routine health information systems. The monitoring of child injury mortality in South Africa needs to be strengthened.

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13 April 2016

HREC REF: 063/2016

A/Prof S Mathews
Department of Paediatrics
Children's Institute
Red Cross War Memorial Children's Hospital
Rondebosch

Dear A/Prof Mathews

PROJECT TITLE: THE SPATIAL DISTRIBUTION OF INJURY MORTALITY OF CHILDREN IN THE WESTERN GEOGRAPHIC SERVICE AREA, CITY OF CAPE TOWN (2011-2015) (PhD-candidate- Ms Z Albertyn)

Thank you for your response letter, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 April 2017.

Please remove the reference to race from all tables in the study protocol.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the following student, Zulfah Albertyn will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur

HREC 063/2016