# Fire Risk and Vulnerability in Urban Informal Settlements in Metro Manila:

## An integrated approach to sustainable urban fire risk management

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Abstract

Urban fires, particularly in informal settlements in rapidly urbanizing cities in the developing world, are an "everyday disaster" that oftentimes goes unnoticed or underserved in the face of disturbances of the more "lethal reputation". These disturbances of normal existence are arguably the most debilitating to vulnerable communities and sustainable development, and yet get little attention in disaster literature or in practice. This thesis set out to highlight the significance of informal settlement fires as part of the overall urban fire problem, and further the understanding of the complex, multi-dimensional, aspects of informal settlements as they relate to urban fire risk and holistic management of urban disasters in a resource-limited environment (in this case Metro Manila). Living conditions in slums are characterized by acute poverty, overcrowding, substandard housing, high levels of un- or under-employment, deficient/insufficient basic services (e.g. water, sanitation), and widespread social, spatial, economic and legal exclusions. Fires in these communities are a daily reality that have short term, but primarily long-term devastating impacts that perpetuate the cycle of poverty and societal inequities. Several theories and quantitative, socio-technical analyses were explored in the context of Quezon City to piece together a complex understanding of IS fires and to better inform decision-makers in developing more comprehensive and sustainable urban disaster risk reduction strategies. The aim is to bring the urban fire problem into the overall disaster risk and sustainable development discourse, such that effective, locally relevant interventions target those in greatest need.



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## Abbreviations

| | |
|---|---|
| BFP | Bureau of Fire Protection |
| CRED | Centre for Research on the Epidemiology of Disasters |
| DRR | Disaster Risk Reduction |
| DRM | Disaster Risk Management |
| EMI | Earthquakes & Megacities Initiative |
| GIS | Geospatial Information System |
| HCDR | Housing, Community Development and Resettlement Department |
| IS | Informal Settlement |
| IFE | Institution of Fire Engineers |
| LGU | Local Government Unit |
| LMIC | Low- and Middle-Income Countries |
| NCR | National Capital Region (aka Metro Manila) |
| POD | Department of Public Order and Safety |
| PSA | Philippine Statistics Authority |
| QC | Quezon City |
| QCDRRM | Quezon City Disaster Risk Reduction Management Office |
| QCG | Quezon City Government |
| TF | Task Force |
| UNDP | United Nations Development Program |
| UNISDR | United Nations Office for Disaster Risk Reduction |
| VGI | Volunteered Geospatial Information |

## Definitions

***Disaster –*** "a situation or event that overwhelms local capacity, necessitating a request at the national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering." (CRED, 2016)

- A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. (UNISDR, 2009).
- A disaster is a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources. Though often caused by nature, disasters can have human origins. (IFRC, 2018)
- "A disaster is the result of a vast ecological breakdown in the relation between humans and their environment, a serious and sudden event (or slow, as in drought) on such a scale that the stricken community needs extraordinary efforts to cope with it, often with outside help or international aid" WHO and UN
- "the occurrence of widespread, severe damage, injury, or loss of life or property, with which the community cannot cope, and during which the affected society undergoes severe disruption." (Perez and Thompson)

***Disaster Management –*** is the aggregate of all measures taken to reduce the likelihood of damage that will occur related to a hazard(s), and to minimize the damage once an event is occurring or has occurred and to direct recovery from the damage. It comprises four stages: prevention, mitigation, response, and recovery.

***Disaster Risk Management*** – The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities to lessen the adverse impacts of hazards and the possibility of disaster (UNISDR, 2009)

***Disaster Risk Reduction*** – The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (UNISDR, 2009)

***Exploratory Data Analysis*** – the development of descriptive statistics, that is, statistical analysis that does not make inferences to a population.

***Fire Engineering*** – "The application of scientific and engineering principles, rules [codes], and expert judgment, based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of people to fire, to protect people, property and the environment from the destructive effects of fire." (IFE, 2018).

***Geocoding*** - is the process of converting physical addresses to a location on the Earth's surface using spatial representation in numerical coordinates (e.g. latitude and longitude).

***Hazard –*** A hazard is anything that may pose a danger; thus, it is used in this discussion to mean a natural or manmade phenomenon or a mixture of both that has the potential to adversely affect human health, property, activity, and/or the environment. ***(***UNISDR, 2009)

***Mitigation –*** any process that is undertaken to reduce the immediate damage otherwise being caused by a destructive force on the society. The lessening or limitation of the adverse impacts of hazards and related disasters.

***Poverty*** – is general scarcity or dearth, or the state of one who lacks a certain amount of material possessions or money.

> ***Absolute poverty or destitution –*** refers to the deprivation of basic human needs, which commonly includes food, water, sanitation, clothing, shelter, health care and education.

***Risk assessment –*** A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. (UNISDR, 2009)

***Slums/Informal Settlements/Shanty Town*** – *"*are characterized by the absence of basic services, such as improved drinking water and adequate sanitation, along with insecure tenure, non-durable housing and overcrowding." (UN-Habitat, 2010)

***Statistical Analysis*** – the use of mathematical methods to condense sizeable bodies of numerical data into a small number of summary statistics from which useful conclusions may be drawn.

***Vulnerability*** – The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. These can be physical, social, economic, political, environmental vulnerabilities.

# Contents

# 1 Introduction

This chapter introduces the context and purpose of the thesis. Firstly, a high-level overview of several complex and interrelated global processes is presented as the setting in which the urban informal settlement fire problem has emerged. This is followed by a description of Metro Manila and the informal settlement fire problem in the Philippines.

## 1.1 BACKGROUND

Since the 1950s, global growth in urban populations has increased exponentially from 746 million to 4.1 billion in 2017, resulting a major shift in global urban-rural distributions from 30% to more than 54% (UNDESA, 2015; WUR, 2014; World Bank, 2018). While most urbanized regions have historically been in North America (82%), Europe (73%) and Caribbean/Latin America (80%), the highest rates of urbanization are currently in Asia and Africa where nearly 90% of urban growth is predicted to occur by 2050 (UNDESA, 2015; WUR, 2014). In these regions, unprecedented urban growth has signified rapid advancements in human-society – increased economic growth, industrialization, improved quality of life, technological/scientific innovation, rise in capitalistic policies, improved medical technology, centralization of government services, wide-spread information/knowledge sharing, etc. (Becker, 2014). However, these developments, particularly in low- and middle-income countries (LMIC), often mask enormous sustainable development challenges – increased stresses to the environment (e.g. air/water pollution, degradation of land, congestion, depleting natural resources, increased waste production, over-consumption) and social/political/physical/economic vulnerabilities and inequalities (e.g. poverty, inadequate basic services, corruption, accumulation of resources in fewer hands, disease, illiteracy, land insecurity) (ESCAP, 2015; UNDESA, 2015). These challenges while affecting the whole of society, disproportionately impact the already 1.2 billion poor and marginalized urban residents living in slums or vulnerable living conditions (UNISDR, 2015/2; CRED, 2015; UN HABITAT, 2016).

Alongside these trends in urbanization has been the exponential increase in recorded natural and man-made disasters, from roughly 24 per year in 1950 to approximately 400 in 2015. These events have not only resulted in major economic losses annually (200 million to 364 billion, respectively) but also affected increasingly larger numbers of people from 50 to 250 million over the same period (UNISDR, 2015/2; CRED, 2015; NISDM, 2013; UNDP, 2015). Cities are particularly vulnerable due to their high concentrations of people and economic assets, and their hazard-prone locations in coastal areas, along rivers, and in seismic zones (Baker, 2011). Due to a complex and dynamic mix of underlying socio-economic, political and environmental vulnerabilities, diversity of hazard exposures and local capacities for resilience, LMICs tend to be disproportionately affected by disasters (UNISDR, 2015/2, Becker, 2014), particularly as 20-50% of the population live in substandard living conditions (Baker, 2011). Since the 1980s, 80% of total life years lost in disasters are spread across LMICs, with economic losses equating to 20% of total social expenditures compared to only 1.19% in North America and <1% in Europe and Central Asia (UNISDR, 2015/2, JICA, 2007). These trends are anticipated to increase further and cut across sectorial, geographical and economic boundaries as the scale, magnitude and diversity of hazards, as well as, anticipated impacts of global-scale climate change and depletion of planetary resources reach a tipping point (UNISDR, 2015/2; Becker, 2014; CRED, 2016). It is therefore not new that management of disaster risks while also satisfying sustainable development goals is a complex and dynamic challenge requiring a shift away from a fragmented, localized mindset to a more collective, multi-disciplinary approach at all levels of abstraction (Cardona et al, 2005).

The recognition of managing disaster risks as a central requisite for sustainable development started in the early 1970s, with more significant cross-cutting, thematic focus by the 1990s and 2000s (Becker, 2014, IDNDR, 1994, UNISDR, 2005, UNISDR, 2015, OECD, 2005; OECD, 2008; OECD, 2011). In support of these efforts, is the growing body of academic and scientific literature addressing various aspects of disaster risk from a variety of disciplines, albeit in many cases in isolation (Cardona, 2004). Much of the disaster literature, however, focuses on the characteristics and impacts of natural hazards particularly those of a "lethal reputation" (e.g. earthquakes, hurricanes). However, a far greater proportion of the world's population, particularly the poor and underserved, are at risk from disasters that go largely unnoticed, or at the very least, uncategorized as 'disaster' (e.g. drought/famine, violent conflict, illnesses, urban fires). These events pass for normal existence in many parts of the world, particularly in LMICs (Hewitt, 1983a; Wisner et al, 2004). See Table 1 and 2. It may be the unexceptional tragedy for those of different economic and political circumstances that influences the optics of what constitutes a "disaster" (Wisner et al, 2004). In any event, one such daily or normal "disaster" that is underrepresented in disaster management literature is the growing rise and impact of urban fires in informal settlement communities (a.k.a slums, shanty towns, favelas, barrios, townships).

*Table 1 - Hazard types and their contribution to deaths, 1900-1999 (Wisner et al, 2004)*

| Hazard Type | Percentage deaths |
|---|---|
| ***Slow onset:*** | |
| Famines - drought | 86.9 |
| ***Rapid onset:*** | |
| Floods | 9.2 |
| Earthquakes, tsunami | 2.2 |
| Storms | 1.5 |
| Volcanic eruptions | 0.1 |
| Landslides | < 0.1 |
| Avalanches | Negligible |
| Wildfires | Negligible |

*Source: CRED at www.cred.be/emdat*

*Table 2 - Deaths during disasters, listed by cause, 1900-1999 (Wisner et al, 2004)*

| Cause of death | Numbers killed (millions) | Percentage deaths |
|---|---|---|
| Political violence | 270.7 | 62.4 |
| Slow-onset disaster [a] | 70 | 16.1 |
| Rapid-onset disaster | 10.7 | 2.3 |
| Epidemics | 50.7 | 11.6 |
| Road, rail, air and industrial accidents | 32 | 7.6 |
| TOTAL | 434.1 | 100 |

*Source: Sivard (2001), CRED at www.cred.be/emdat*

Notes: *[a] this figure was increased by Wisner et al (2004) from 18million to 70 million to account for the large-scale underreporting of deaths from drought and famine.*

Of the 1.2 billion people living in slums globally, approximately 881 million reside in urban areas in developing countries. Living conditions in slums are characterized by acute poverty, overcrowding, high levels of un- or under-employment, deficient/insufficient basic services (e.g. water, sanitation), and widespread social- and land-tenure insecurities (UN-Habitat 2003). They often suffer from greater spatial, social and economic exclusion from the benefits and opportunities afforded to other urban dwellers and are exposed to higher levels of physical vulnerability as most are situated in high hazard areas (e.g. flood zones, fault lines, toxic sites, and utility land) (UN-Habitat, 2012). Since 2000, it is estimated that 6 million people are added to the global slum population each year or 16,500 persons/day. This is only anticipated to worsen as the plurality of opportunities in urban centers continue to motivate rural-urban migration, and urban centers continue to struggle to keep up with the rapid expansion (Singh, 2017). Most of this growth is anticipated in urban populations in Asia and Sub-Saharan Africa where those living in urban slums compared to rural areas is currently 28% and 39%, respectively, and is expected to double by 2030 (UN-Habitat, 2015). The sub-standard conditions and anticipated increases in slum populations present enormous challenges for sustainable urban development including how best to manage risks of all typologies – the "lethal reputation" and "daily" occurrence – as even minor incidents can be equally devastating (Pharaoh, 2012).

Urban fires, considered by many as "daily" disturbances, are an ever-present threat in informal settlements (IS) and frequently go underreported and/or downplayed as "normal" emergencies (UNISDR, 2015; Wisner et al, 2004). Catastrophic urban fires are not a new disaster threat, however. Major urban conflagrations devastated many western cities in the past (e.g. Rome in 64 CE, London in 1666, Chicago in 1871, and Boston in 1872). The 1906 San Francisco earthquake and subsequent fire destroyed nearly 90 percent of the city (25,000 buildings, equivalent $8.97 billion in losses), while the 1923 Tokyo earthquake and fire killed over 100,000 people (Dando-Colling, 2010; SFPE Handbook). These historic fire events led to the development of modern building codes, land-use planning, emergency services, citizen awareness, and insurance regulations, such that catastrophic urban fires are no longer an intensive risk particularly in the U.S., Europe and other developed nations (GFDRR, 2014a).

However, modern fire and building codes, land use planning and other urban fire preventive measures have not been broadly adopted, implemented and/or enforced in many parts of the developing world (Bilham, 2009). In urbanizing cities in LMICs, building construction practices, use of combustible/lightweight materials, insufficient egress, hazardous ignition sources, limited occupant notification systems, limited fire fighter provisions (e.g. vehicle access, fire hydrants etc.) and lack of planning for IS areas are arguably like the conditions that once existed in cities of the great urban fires of past. Given these physical vulnerabilities coupled with underlying socio-economic and political challenges described earlier, fires in IS areas are not only frequent but have devastating short-term physical, economic (damaged/destroyed property, use of public emergency services and health care), life-safety (injuries, deaths) impacts as seen in Figure 1, Figure 2 and Table 3.

*Figure 1 – Aftermath of devastating informal settlement fire in Tondo, Manila, Philippines, on February 9, 2017, leaving 1,200 buildings destroyed, 15,000 people displaced, 1ha burned, and costing $140,000 in damages. A similar fire occurred the year before destroying 1,000 homes. © Romeo Ranoco / Reuters*

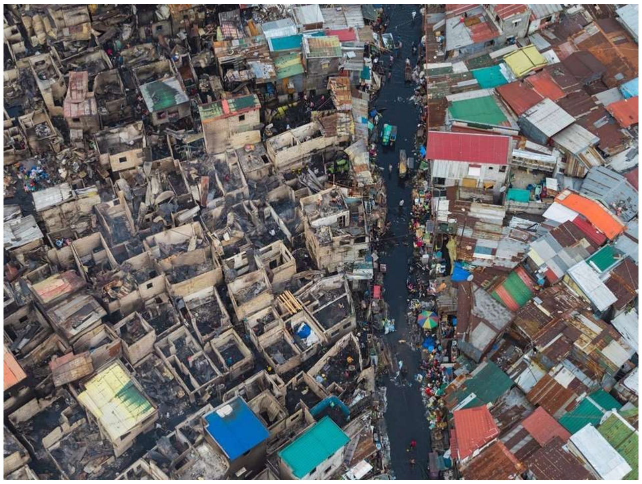


*Figure 2 - Aerial photograph of informal settlement fire in Tondo, Manila. © Barnhard Lang*

*Table 3 – List of informal settlement fires internationally in recent years (1994 – 2018)*

| Date | Location | Deaths | Injuries | Houses Destroyed | People Impacted | Damages |
|---|---|---|---|---|---|---|
| 2018-04-22 | Gurugram, India | - | | 150 | 500 | |
| 2018-03-13 | Illias Molla, Dhaka, Bangladesh | - | 4 | 8,000 | | |
| 2018-01-29 | Kijiji, Lang'ata, Nairobi, Kenya | 4 | | | 6,000 | |
| 2017-02-09 | Tondo, Manila, Philippines | - | 7 | 3,000 | 15,000 | $140,000 |
| 2015-07-21 | Jakarta, Indonesia | - | | 160 | 1,000 | |
| 2013-04-12 | Delhi, India | - | | 400 | 2,000 | |
| 2013-03-15 | Kayamandi, Cape Town, S. Africa | 3 | | 1,300 | 4,000 | |
| 2013-01-01 | Khayelitsha, Cape Town, S. Africa | 5 | | 800 | 4,000 | |
| 2012-05-21 | Old Fadama, Accra, Ghana | | | | 3,500 | |
| 2011-09-11 | Mukuru-Sinai slum, Nairobi, Kenya | 120 | 116 | 77 | | |
| 2011-03-04 | Garib Nagar, Mumbai, India | | 21 | 700 | 2,000 | $86,000 |
| 2011-02-14 | Bahay Toro, Quezon City, Philippines | 1 | 6 | 2,000 | 10,000 | $200,000 |
| 2009-06-12 | Agua Espraiada, Sao Paolo, Brazil | | | 250 | | |
| 2009-01-09 | Karachi, Pakistan | 39 | | 40 | 200 | |
| 2005-01-15 | Joe Slovo, Lange, Cape Town, S.A. | | 7 | 2,590 | 12,950 | |
| 2004-02-01 | Imizamo Yethu, Cape Town, S Africa | | | 1,200 | 5,000 | |
| 1994-02-04 | Quezon City, Philippines | 3 | 3 | 1,500 | 7,000 | $200,000 |

***Note: Data for Bangladesh from Ahmed (2014); for India Retd (2016); for Kenya Gachago (2013); for Indonesia Rahmawati (2015); for South Africa Pharoah (2017), Walls et al (2017); for Philippines (BFP); for Brazil Claret (2012) and Ono (2000); for Ghana Owusu (2015); for Pakistan Westwell (2011)***

Table 3 illustrates the physical impact of several large IS fires that have occurred globally in recent years. In all cases, 10s to 1000s of homes are destroyed with 1000s of people displaced and many millions of dollars lost in direct/indirect damages every year. These primary losses, however, ignore the secondary impacts on health (disability, psychological trauma), environment (water/air pollution from fire debris and contaminated water runoff), social structures, local economies and long-term societal development that perpetuate a cycle of poverty and societal inequities (Hummel, 1967). The labelling of urban IS fire as “normal” or “daily” is arguably misguided, as these frequent reoccurring disruptions have far greater and debilitating impacts than the major and less frequent natural hazards that typically get more attention (Wisner et al, 2004; UNISDR, 2009).

## 1.2 METRO MANILA – A COMPLEX, SPRAWLING URBAN AGGLOMERATION

One rapidly urbanizing Asian city faced with a significant IS fire problem is Metro Manila, also known as the National Capital Region (NCR) of the Philippines. The NCR – the seat of Philippine political-, social-, economic-power – has experienced one of the highest rates of urban growth in the developing world from 1.5 million in 1950 to 12.8 million people in 2016 (UNDESA, 2015; USAid, 2011). While this has led to strong economic growth, industrialization, technological advancements, enhanced political power, expanded infrastructure and higher quality of life, it has also resulted in one of the most inequitable and polluted cities in the world (UNDESA, 2015; Singh, 2017). One only needs to refer to the breadth of literature for evidence of the variety of ailments befalling Metro Manila – average density of 43,079 people/km$^2$ (CIA, 2015), severe congestion, air/water/soil pollution, degradation of natural resources, housing crises, inequitable wealth distribution, poverty, biodiversity loss, etc. (LCP, 2004; ADB, 2013; Singh, 2017). It is also estimated that at least one-third of Manila's urban population (~4.5 million) lives in slums (NEDA, 2011) and is projected to grow at 6.2 percent annually.

Every week, fires in urban ISs undermine fragile livelihoods and further compound existing vulnerabilities and ongoing threats from frequent natural hazards in the region (i.e. flooding, typhoons, earthquakes). Fire-related events over the past 10 years (avg of 3,948/year) have resulted in the loss of at least 914 lives, 3,105 injuries and 100s of millions of USD, much of which has occurred in urban slums (BFP, 2018; CDRC, 2009/2011/2013). The actual figures are estimated to be significantly higher due to under-reporting commonly observed in marginalized communities (CRED, 1996). See Figure 3.

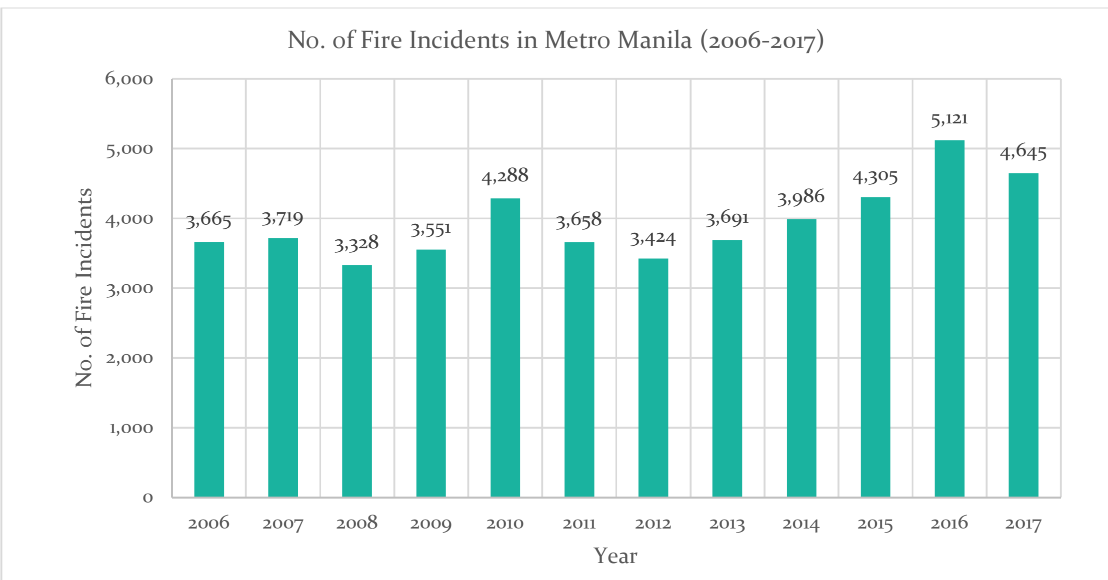



*Figure 3 - Recorded fire incidents in NCR from 2006-2017 (PSA)*

A recent IS fire in Metro Manila, occurred February 2017 in the Parola Compound Tondo, resulting in 15 injuries, 15,000 homeless and millions of pesos in property losses (BFP, 2018). See Figure 1 and Figure 2. Unfortunately, fires in this area like so many others are a reoccurring event. See Table 4.

*Table 4 - Fire prone large informal settlements in Metro Manila (2006 - 2016)*

| City | Location | No. of incidents | Deaths | Injuries | Damages | |
|---|---|---|---|---|---|---|
| Manila | Parola Compound | 16 | - | 3 | ₱ 4,500,000 | $90,000 |
| Manila | Baseco Compound | 11 | 1 | - | NR | |
| Quezon City | NIA road | 4 | 5 | 14 | NR | |
| Quezon City | Agham Road | 13 | - | 2 | ₱ 10,000,000 | $200,000 |
| Mandaluyong City | Welfareville | 20 | 3 | 9 | ₱ 25,000,000 | $500,000 |
| *Source: BFP-NCR* | *NR – Not reported* | | | | | |

Comparing the impact of fire incidents to other disaster events, nationally, urban fires occur the most frequent, and have the second largest, average, annual deaths and economic losses after typhoons (BFP, 2017; PSA, 2017; CDRC, 2013). See Figure 4, Figure 5 and Table 5

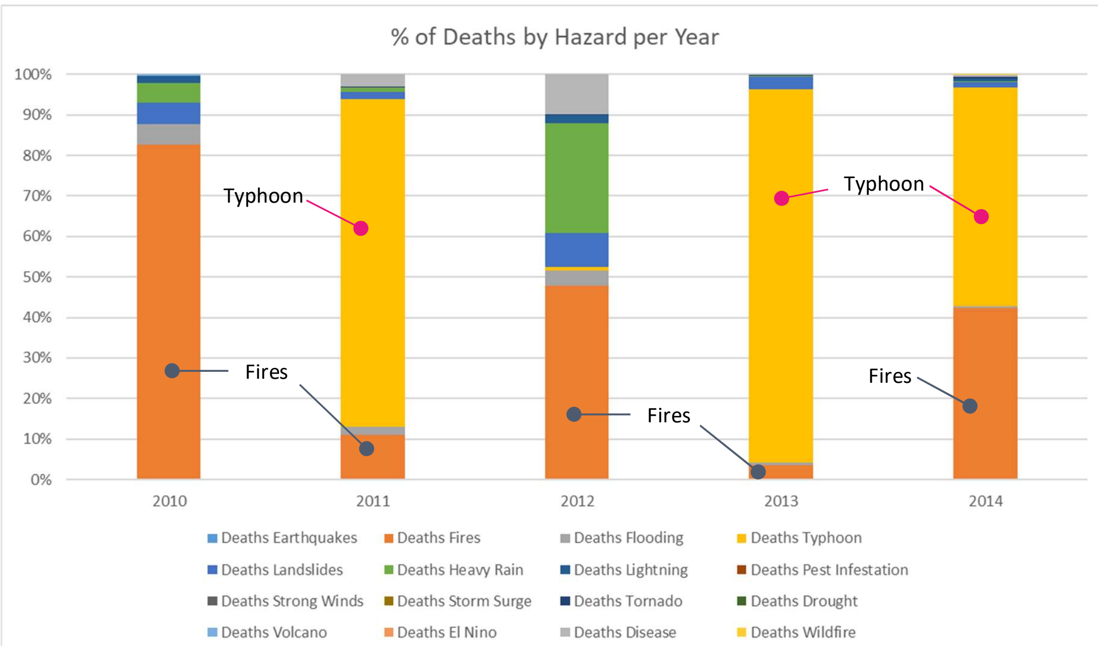



*Figure 4 - Percentage of Deaths by Hazard per Year (2010-2014)*

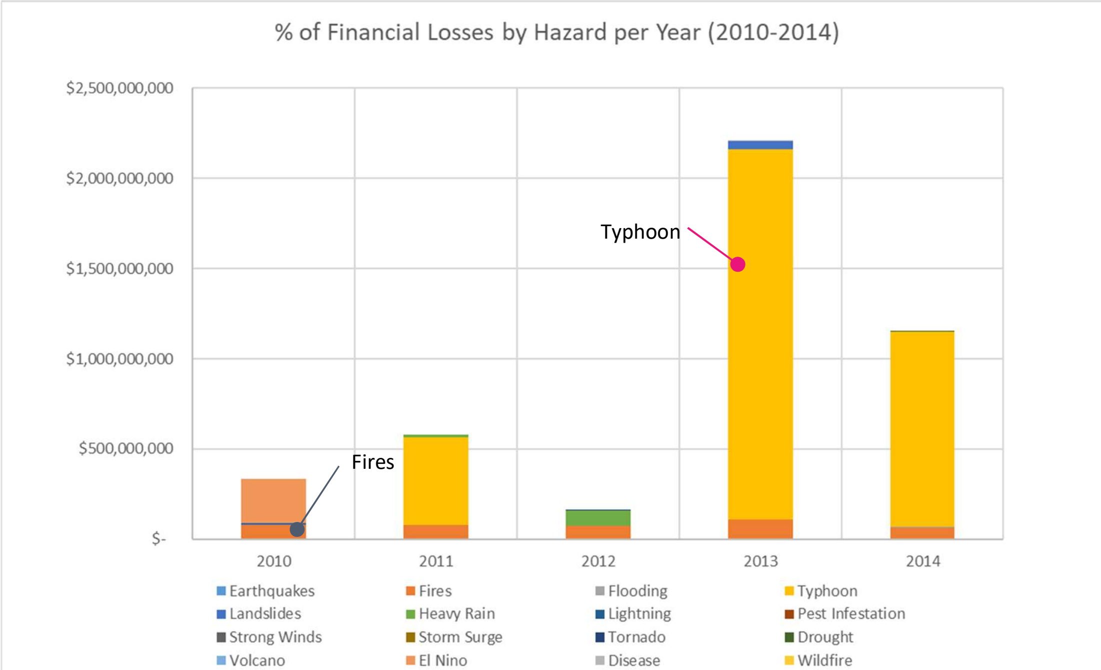



*Figure 5 – Direct Economic Losses by Hazard per Year (2010-2014)*

*Table 5 - Economic and life losses by hazard (2010-2014) (PSA)*

| Hazard | USD ($) | % of Total | Rank | Deaths | Rank |
|---|---|---|---|---|---|
| Earthquakes | $ 320,380 | 0.01 | 8 | - | |
| Fires | $ 409,380,000 | 9.25 | 2 | 1,253 | 2 |
| Flooding | $ 5,634,040 | 0.13 | 6 | 125 | 5 |
| Typhoon | $ 3,618,444,120 | 81.74 | 1 | 8,422 | 1 |
| Landslides | $ 45,346,340 | 1.02 | 5 | 332 | 3 |
| Heavy Rain | $ 92,741,000 | 2.09 | 4 | 193 | 4 |
| Drought | $ 3,789,580 | 0.09 | 7 | - | |
| El Nino | $ 242,142,500 | 5.47 | 3 | - | |

Despite the significance of urban fires in the overall disaster space and the recognition of the devasting impacts of IS fires by various agencies in Metro Manila, there has been limited analysis of the overall fire problem from currently collected fire data, let alone, specific data collection and analysis of the nature (e.g. fire characteristics, impacts, ignition sources, combustible fuel loads, egress/access issues, firefighting provisions, etc.) and socio-technical challenges of IS fires to guide city planning (Balahadia, 2017). The limited data-driven science may also reflect the lack of disaster related knowledge of how to manage urban IS fires as part of a holistic disaster management strategy.

Furthermore, little is understood about the risks introduced by IS fires beyond the community itself – to natural resources (water, air, soil), first responders, “formal” residents, as well as, critical infrastructure, city services and “formal” structures/buildings. The challenge of fire risks in ISs may not be that they present new, unknown fire science issues. That is, it is well documented in fire safety literature of the increased fire safety risks when structures/communities are built with little to no fire safety awareness, planning, standards and/or regulation (Jennings, 2013; NFPA, 2003; SPFE, 2002). The challenge may be in predicting the extent of impact to IS communities, which tend to be non-homogenous in technical fire safety issues, typologies, size, and socio-economic and coping capacity characteristics (Singh, 2017). The combination of all these components present an unknown fire risk to informal settlers, as well as, first responders, and the surrounding community.

These contextual issues not only present unique challenges and complexities in developing a holistic understanding of fire risks in ISs, but also in the development of management strategies that are locally pragmatic, sustainable and mainstreamed across relevant stakeholders and levels of administration. Because of the complex, multidimensional nature of the issues, a single perspective to assessing fire risks and developing management strategies to prevent, mitigate and/or adapt may be misguided. A socio-technical, multi-disciplinary perspective – as a general approach – may provide enhanced insight into this complexity and therefore provide a more comprehensive and holistic basis for decision-making.

Therefore, this thesis examines the context, nature, and consequences of fire risk in ISs in Metro Manila, as well as, the insights gained through statistical, geospatial and urban disaster risk indexing analyses of historical fire data. In so doing, it aims to contribute to knowledge of "everyday" fire threats on the conceptualization and drivers of disaster risk in urban areas in the Philippines (and more broadly rapidly developing cities in Asia), and draw out lessons for prescriptive fire risk reduction intervention, both in the Philippines and elsewhere.

## 1.3 THESIS OUTLINE

This thesis is organized as follows:

- ***Chapter 2*** presents the main research aims, as well as, the formulation of more specific research questions.
- ***Chapter 3*** presents the theoretical framework underpinning the thesis
- ***Chapter 4*** describes the methodology and materials
- ***Chapter 5*** presents the results of the various analytical studies
- ***Chapter 6*** provides a discussion of the results and how it contributes to the current state of knowledge
- ***Chapter 7*** offers conclusions from the thesis and suggestions for future studies

Several Appendices are included to provide supplemental details from the analytical work

## 2 Research Aims and Questions

The primary aim of this thesis is to better understand the significance of IS fires as part of the overall fire problem in a rapidly urbanizing city and to provide increased knowledge into the characteristics and nature of this unique risk as part of holistic urban disaster management.

Since research into the urban IS fire challenge is quite limited and in its early phases of understanding, I elected to adopt an explorative approach to my research. An explorative approach allows for a plurality of epistemological perspectives (Healy, 2003) in formulating a research question, as well as, devising the method by which research will be undertaken. By having this approach and evaluating a problem from a range of methods and perspectives facilitates a broader, complex understanding of the challenge with the aim of better informing, comprehensive and pragmatic strategies in a practical setting (Bergstrom, 2014). That is, in this context, to perform a variety of analyses to gain a complex understanding of fire safety risks in urban ISs and to use this as the basis for informing more holistic and sustainable disaster management strategies.

As such, the following research questions have been explored:

- What is the significance of the overall urban fire problem in the Philippines compared to other disaster events, and other countries/cities internationally?
- What are the societal **fire risks** – frequency of incidents and primary physical impacts (deaths, injuries, economic losses) – of urban fires in ISs in Metro Manila?
- What are the characteristics of urban IS fires in Metro Manila? What **technical factors** (e.g. construction materials, over-crowding, insufficient egress/access, lack of fire suppression, combustible materials) based on fire engineering principles contribute to fire risks in ISs?
- What **underlying vulnerabilities and capacity weaknesses** – social, economic, political, administrative, legal – further exacerbate fire risks in IFS? And why?
- What socio-economic indicators correlate well with fire incident frequency and severity of urban fires? How does ISs influence these indicators?
- What modifications can be made to the currently adopted urban disaster risk indexing system in Metro Manila to integrate urban fire risks into a comprehensive, multidisciplinary perspective of total urban disaster risk?

# 3 Theoretical Framework

The theoretical framework underpinning this thesis lies at the intersection of several fields of research – Fire Risk & Vulnerability, Fire Safety Engineering, Urban Informal Settlements & Multi-Dimensional Poverty, Complexity Theory & Systems Perspective, and Disaster Risk Management. These fields/concepts served as a vehicle for obtaining a more complex understanding of the various dimensions of fire risk, urban disaster risk management and urban ISs. While the focus of the work has been derived from the field of risk, several related concepts and fields of research provide a critical backdrop to the challenges faced by disaster managers in developing sustainable and locally relevant management strategies particularly in a developing world context.

A detailed discussion of the theories and concepts underpinning the thesis are provided in Annex A.

# 4 Methodology

This thesis consists of two main parts. The first part consists of a review of existing literature to provide general background information, identify previous studies and acquire state-of-the-art knowledge of the complex set of issues associated with fire risks in urban ISs. The introduction and theoretical framework document much of the review of underlying contextual issues, while Section 5 primarily focuses on the current state of IS fire research.

The second part presents a combination of quantitative methods to not only achieve a complex understanding of the multi-dimensional nature of fire risks in urban ISs in a developing world context; but also, to develop and/or enhance decision-making tools for holistic urban fire DRM. It is also exploratory in nature due to the limited literature on assessing fire risks in IS areas and the limitation of most methodologies being designed to evaluate fire risks at the building level, and not at the neighborhood or city level, nor for LMICs with significant underlying socio-economic, political, legal, economic, and administrative barriers. Refer to Annex A.1 and A.2. The use of a multi-analytical approach is also a pragmatic necessity as a single analytical method would provide limited insight given the inconsistent and incomplete data available locally. In some ways, the selected methods were driven, not only by the data, but also by the time and resource constraints of the project, existing local disaster risk management strategies and capacities for knowledge transfer/absorption.

Note: While the analyses are primarily quantitative in nature, the process of undertaking the work was also informed by qualitative inputs (i.e. interviews with key QCG officials, Barangay captains and local IS residents, field survey of local IS communities). These helped to provide local insight (i.e. perceptions, behaviors and attitudes) and substantiate the analytical methods adopted (as relatively easy entry points to enhancing urban fire risk knowledge and management practices).

Figure 6 provides a schematic overview of the overall methodology adopted in this study. Refer to Annex B for a detailed discussion of the methodology, key limitations and reliability/quality of the research.

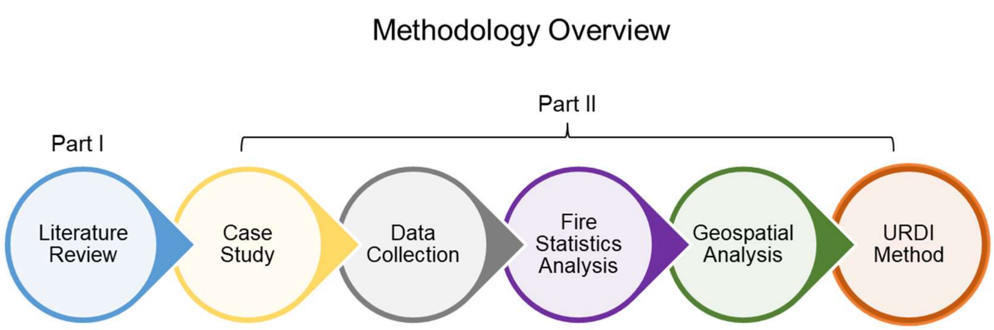



*Figure 6 – Overview of thesis methodology*

# 5 Literature Review

## 5.1 OVERVIEW OF INFORMAL SETTLEMENT FIRE RESEARCH

As mentioned early, great urban conflagrations are not a new phenomenon in either the developed or developing world. Metro Manila since its inception in the 16th century was plagued with frequent major urban fire events (Bankoff, 2012), while other major cities in the West also experienced great historical fires (e.g. London in 1666). Most agree that these great fires are associated with some form of rapid societal change – industrialization, rapid urbanization, poor urban planning, massive concentration of wealth/resources, and limited enforcement/regulation of urban fire safety principles (Bankoff, 2012; Zhang, 2018; Ahmed, 2014; Tadie, 2013). With the inception of building/fire code regulations in response to these historical fire events, urban conflagrations appeared to be something of the past (GFDRR, 2014a), particularly for more developed countries. However, in many parts of the developing world, where rapid urbanization is currently prominent, issues with major urban fires is striking again. This time, however, the issues and focus are primarily on a variety of underlying societal issues (e.g. socio-economic deprivations, policies issues, limited resources, lack of reliable data, corruption, lack of urban planning) impacting vulnerabilities communities such as ISs, rather than a total lack of general fire safety knowledge and/or building & fire codes (Twigg et al, 2017).

In the past fifteen years, there has been a modest resurgence of interest in urban fire risk and associated socioeconomic drivers for these risks (Jennings, 1999; Corcoran et al, 2011, Jennings, 2013). A subset of this interest has been focused on fires in urban ISs. While there has been a fair amount of research in IS fires in South Africa (Pharoah, 2009; Walls et al, 2017; Walls et al, 2017; Zweig & Pharoah, 2017; Morrisey, 2006; MacGregor et al, 2005; Harte, 2009) and to some extent Ghana (Owusu M, 2013), Bangladesh (Ahmed, 2014; Maniruzzaman, 2013), India, Nepal, Chile, Brazil, etc. (Ono, 2000; Twigg et al, 2017), little research has been undertaken in the Philippines (World Bank Group, 2017; Ingal et al, 2016; Balahadia,2017; Velasco, 2013).

Of the work that has been undertaken internationally most is limited in scope and methods (e.g. community-based methods, descriptive approaches, interviews/focus group discussions, descriptive statistical analyses), and is context specific. The few preliminary studies undertaken in the Philippines only explore general fire safety in the City of Manila to a limited extent – e.g. highlighting simple fire statistics, peak times of year/day, main ignition sources (e.g. cooking, faulty wiring) and some fire operation limitations. The IS fire problem is only briefly mentioned as contributing to the overall fire challenge in Manila due to sub-standard conditions (e.g. high population, makeshift housing, housing density, narrow alleys, faulty wiring, lack of water) and lack of code enforcement, but is not the focus of the studies (Balahadia, 2017; Velasco, 2013; Singh, 2017).

## 5.2 PHYSICAL AND SOCIOECONOMIC FIRE RISKS

While the technical fire safety challenges of ISs are generally considered well understood from urban fire safety principles in the literature (NFPA, 2003; SFPE, 2002), there still appears to be limited research explicitly verifying these understandings in the IS context. Although not quantified, much of the literature (Singh, 2017; Twigg et al, 2017) associates the physical fire risks of informal settlements to the following, in ***Table 6***.

*Table 6 - Physical factors contributing to fire risk in IS Areas*

| Thematic Areas | Contributing Physical Factors |
|---|---|
| Population | • High-density population |
| Built Environment | • High-density construction<br>• Poor construction<br>• Structures comprised of a mixture of highly combustible, lightweight, materials (e.g. plywood, makeshift materials, native woods/grasses, timber), as well as, non-combustible materials of varying inherent fire resistance levels (e.g. corrugated sheet metal, concrete blocks, steel rods/rebar) |
| Access and Egress | • Irregular, limited, and narrow means of access and egress Limited fire department personnel/equipment and vehicle access |
| Ignition Sources | • Limited access to safe energy options for cooking and lighting |
| Fuel Load | • Poor waste management practices<br>• Unknown types and amounts of hazardous and flammable materials |
| Suppression | • Limited or deficient means of local and/or community-level suppression (e.g. fire extinguishers, water supplies, fire hydrants, fire hoses, sprinklers) |
| Fire Detection and Alarm | • Lack of automatic fire/smoke detection<br>• Limited means of occupant/community notification |

While physical risks are critical components, research in the last 15 years has primarily focused on the many broader socio-economic vulnerabilities influencing the severity of fire impacts as was discussed in Annex A.3 and more extensively in the literature (Ahmed, 2014; Harte et al, 2008; Tadie, 2013).

## 5.3 RESOURCE LIMITATIONS FOR RESEARCH AND MANAGEMENT

Unlike the developed world, fire policies and management strategies in developing countries are often constrained by lack of capacity and resources (Twigg et al). These limitations can range across several sectors and to varying degrees – finances, staffing, expert knowledge, skills, institutions, physical resources, time, technologies, etc. This makes the task of analyzing and developing solutions for specific fire problems (such as IS fires) in a resource-constrained context a major challenge.

One key area where constrained resources has significant impact is in the inadequate and uneven level of data availability on incidence, impacts and causes of informal settlement fires in the developing world (Twigg et al, 2017; Whitby, 2015). Researchers also noted data limitations on vulnerabilities, inconsistent and incompatible data collection frameworks, and limited technologies for data management (Whitby, 2015; Ingal et al, 2016). Even when databases are established to collect a distribution of disaster types including fires (e.g. DesInventar, EMDAT), there is still an insufficient level of detail or refinement to make inferences about ISs. These limits in data have resulted in a number of country, city or community level case studies (e.g. South Africa, Ghana, Brazil, etc.), where the scale, nature and solutions to informal settlement fires have been conducted using a variety of approaches (Rosenburg, 2013; Pharoah, 2009; Owusu A, 2013; Walls et al, 2017; Zweig & Pharoah, 2017; Morrisey, 2006; MacGregor et al, 2005; Harte, 2009). But, as with single case studies, making inferences to broader and/or different contexts – socioeconomically, politically, culturally, construction practices, access to services, behavioral traits, cooking methods, lighting methods, and fire management capacities – can be misguided. This was observed in the MANDISA project (Monitoring, Mapping and Analysis of Disaster Incidents in Southern Africa), an extensive data collection system used to gather fire incident data in Cape Town as a vehicle for supporting decision making and strategic planning. This project demonstrated the multi-dimensionality of the factors contributing to fire incident and impact, even within the same country conditions (Pharoah, 2009).

Some parallel inferences have been made from epidemiological studies to assess fire life safety impacts and severity of injuries, locations of fires and immediate causes of injuries (Velasco, 2013; Godwin et al, 1996; Kimemia, 2017; Wong et al, 2013). Other inferences have also been made to research and non-academic research on fires in camps and refugee settlements (Kazerooni et al, 2016), but it's unclear if these inferences have the same underpinnings and societal impacts compared to more established urban informal settlements as part of megacities.

## 5.4 FUTURE RESEARCH AND ANALYTICAL TOOLS

While informal settlement fire research in the past 15 years has used a variety of analytical approaches– e.g. community-based methods, descriptive approaches, interviews/focus group discussions, descriptive statistical analyses – primarily focusing on socio-economic drivers, future research seems to be leaning towards GIS technologies (i.e. spatial and temporal analysis, spatial statistics, spatiotemporal analyses) as an analytical tool. Several of these approaches have been reported in the literature (Alam, 2004; Zhang, 2018; Corcoran et al, 2007; Corcoran et al, 2011) albeit not directly addressing IS fires. There have been a few examples of GIS use for IS fires in the developing world (e.g. Sufianto & Green, 2012; Maniruzzaman & Haque, 2013; URI, 2004). These studies have provided understanding into general fire statistics (e.g. damages, causes, casualties, response times, nature of fires, etc.). But, broader uses in the developing world may be limited by constraints on local resources, technical capacities, and/or relevant, complete and readily available datasets for both fire incidents and census-type information (as mentioned in Section 5.3). In this regard, ISs present specific challenges with GIS tools, such as reliable geocoding due to lack of formal addresses, ongoing changes in physical dimensions, structural changes, new communities, and lack of easily defined boundaries (Twigg et al, 2017).

In addition to GIS tools, there is some work being conducted in South Africa and UK to explore fire engineering and fire science-based approaches (e.g. fire modelling, computer fire simulations, compartment fire testing, flame spread modeling and urban wildfire modelling) to gain different insights into shack fire dynamics at different scales, and to use fire science-based knowledge to inform technical solutions (Walls et al, 2017). This work appears to be promising and to provide a different insight from the socio-economic and risk assessment perspectives undertaken so far. However, due to limitations and constraints previously mentioned, fire engineering sciences may also not have broad applications in much of the developing world or be scalable to city wide applications.

Twigg et al (2017) provides a review of some alternative approaches that have had numerous applications in the developing world and may provide avenues to explore for IS fire research. Refer to discussion for more details.

# 6 Study Area Overview

## 6.1 QUEZON CITY

Quezon City, Philippines – the largest (in area and population) of 17 cities comprising Metropolitan Manila also known as the National Capital Region and the former national capital (between 1948-1976) – is the largest, most rapidly growing city with the largest informal settlement population per capita in the Philippines (QCDRRMO, 2013/1). Covering a total area of 160 $km^2$ (16,000 ha), the 2015 Census reports that QC has a population of 2,936,116 (a 6% growth since 2010) 30% of which are estimated to informal setters (approx. 1 million) (Cruz, 2010). The city has an annual GDP of $320 million (₱ 16,657 million) with projected growth to continue at 8.7% (QCG, 2016). This urban area is experiencing rapid physical redevelopment, growth, and population expansion (QCG, 2016). The city is bordered by Manila to the southwest, by Kalookan and Valenzuela City to the west and northwest. To the south lies San Juan and Mandaluyong, with Pasig City and Marikina City to the southeast. Across the Marilao River lies San Jose del Monte in the province of Bulacan, while to the east lies Rodriguez and San Mateo, both in the Rizal province. See *Figure 7*

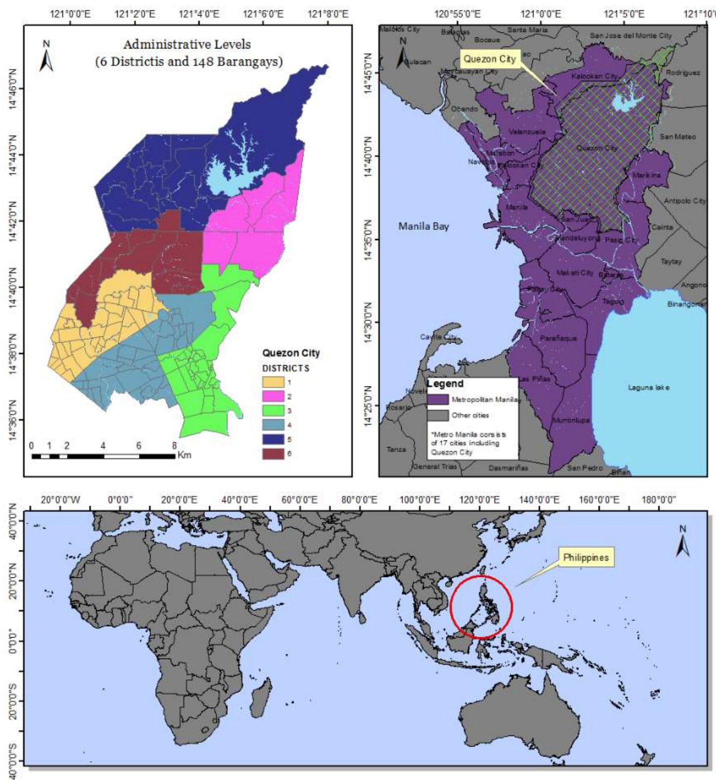




*Figure 7- Geographic location and administrative details of the study area - Quezon City, Metro Manila, Philippines*

Administratively, the city consists of six congressional districts and 142 barangays – the lowest administrative level of government in the Philippines. See Figure 8. The city has a variety of land-uses from high-density residential areas and commercial zones (6%), to open areas, parks and government services.

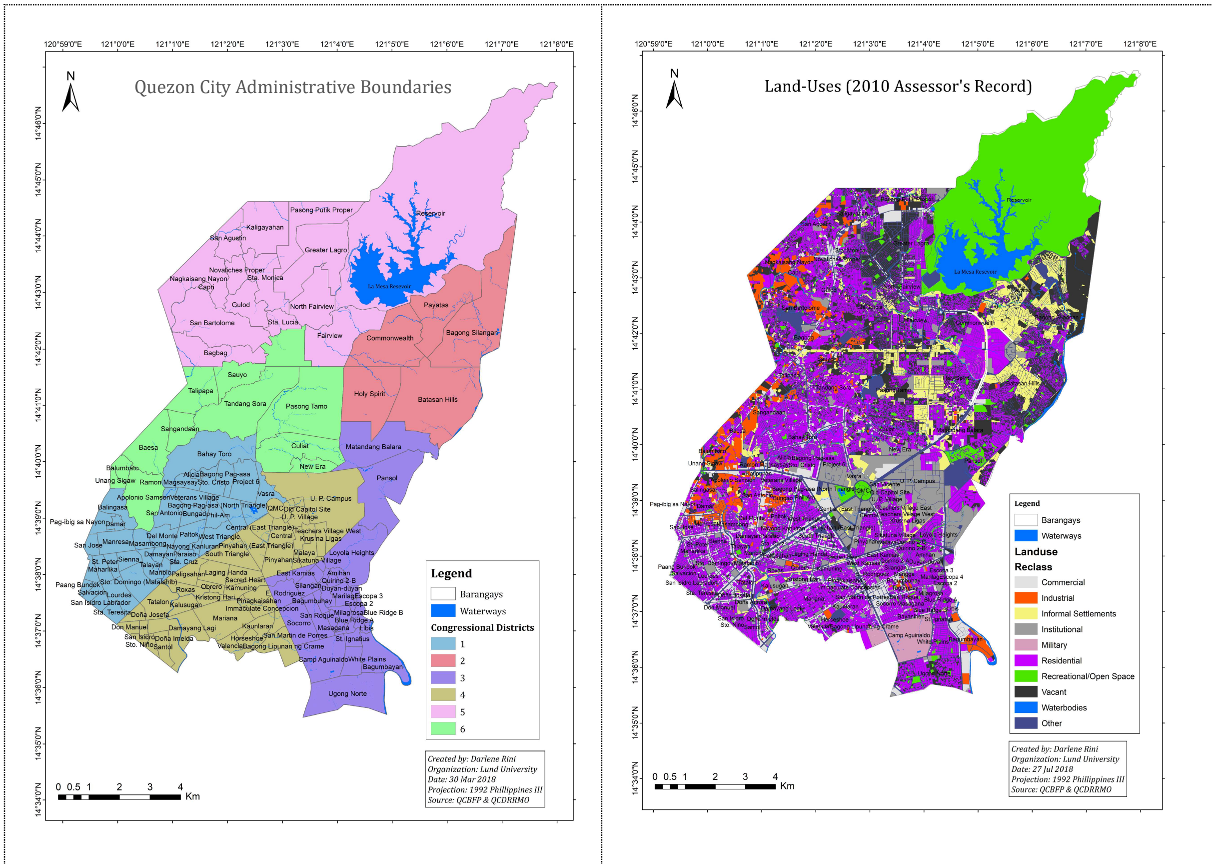
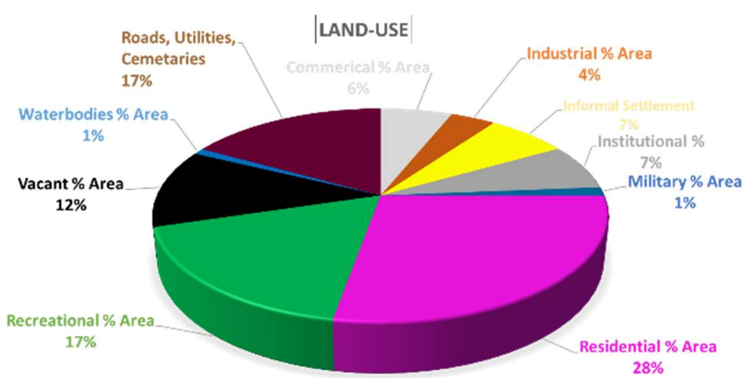



*Figure 8 – (Left)*Administrative boundaries for Quezon City – 6 congressional districts and 142. (Right) Land-uses based on 2010 Assessor's office. Quezon City is primarily residential




| Land-use | % of Land Area |
|---|---|
| Residential | 28% |
| Recreational | 17% |
| Other | 17% |
| Vacant | 12% |
| IFS | 7% |
| Institutional | 7% |
| Commercial | 6% |
| Industrial | 4% |
| Military | 1% |
| Waterbodies | 1% |

*Figure 9 - Percentage land-use areas based on 2010 Assessor's office records*

As seen in Figure 8 and Figure 9, Quezon City is primarily residential (purple) at 28% of the total land area. In addition, a large percentage of the area is occupied by informal settlements (~7%) based on the Assessor office records. However, figures from the CPDO (City Planning and Development Office) and UPAO (Housing and Community Development and Resettlement Office) indicate a much larger area of informal settlements of approximately 10.4% (See Figure 15).

With respect to physical profile, Quezon City's natural terrain is generally flat (from 0 to 259m in elevation) as it sits primarily on the Central Plateau with slopes ranging from 8-15° near the West Valley Fault line (eastern border of the city) and the La Mesa Reservoir to the northeast. The city also has five principle river basins, principally Quezon City River, San Juan River, Marikina Rivers and Meycauayan River – that create a network of 44 tributaries. See *Figure 10*. It is along many of these waterways and fault lines that many of the IS populations live.

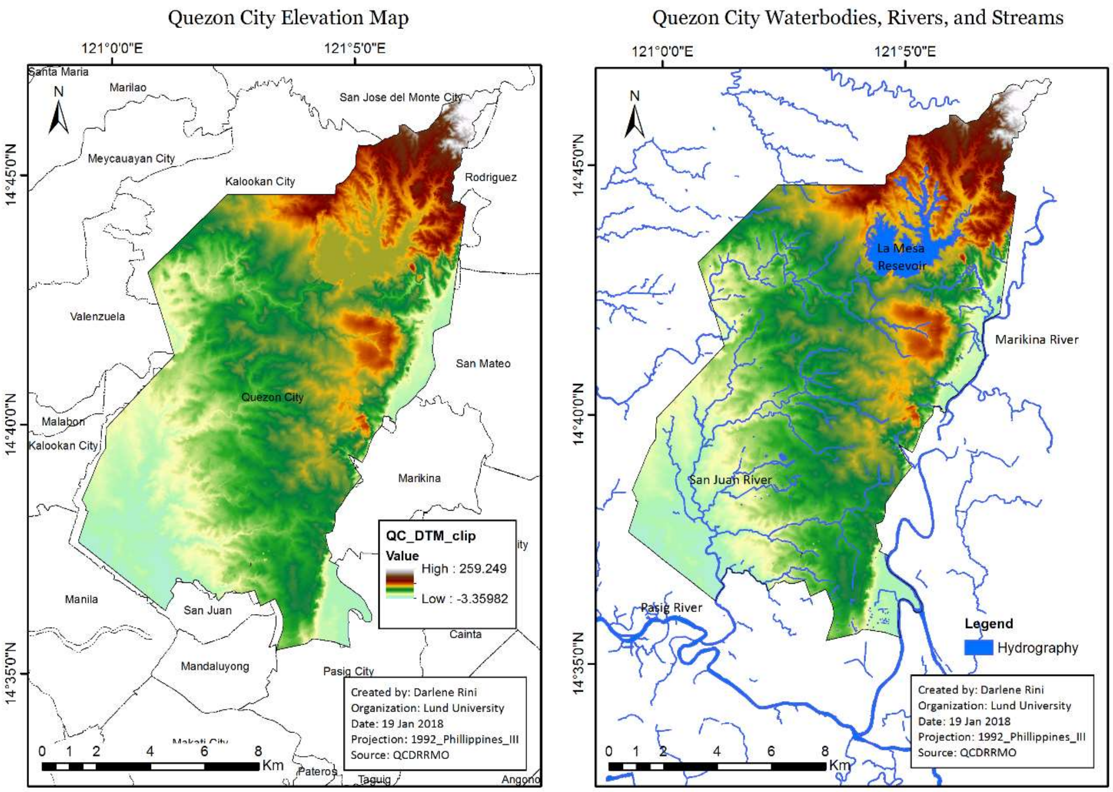
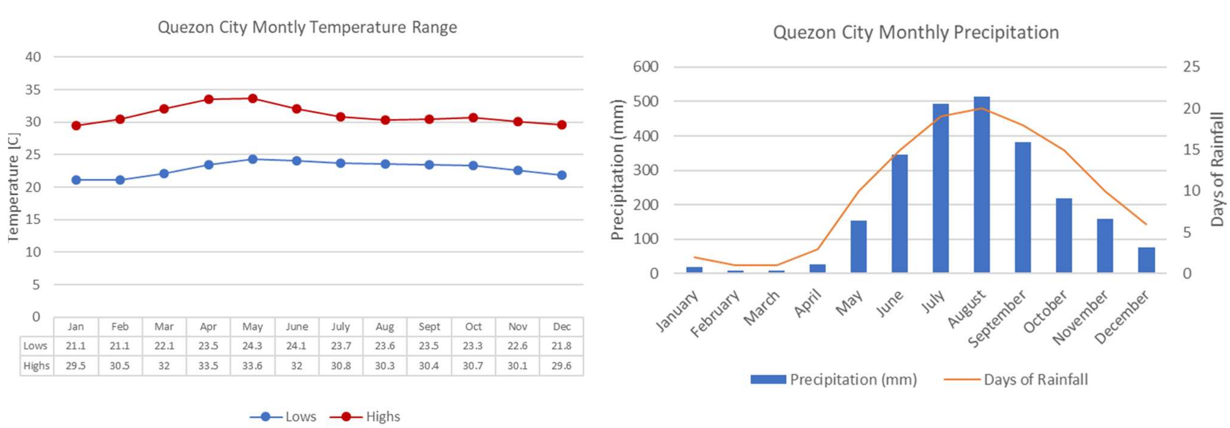



*Figure 10 – Quezon City elevation map (left). Map of waterbodies, rivers and streams in QC (right)*

QC has three distint seasons – a cool dry season (Nov-Jan), a hot dry season (Mar-May) and long rainy season (Jun – Oct). *Figure 11* illustrates the monthy temperature and precipitation levels throughout the year.




| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lows | 21.1 | 21.1 | 22.1 | 23.5 | 24.3 | 24.1 | 23.7 | 23.6 | 23.5 | 23.3 | 22.6 | 21.8 |
| Highs | 29.5 | 30.5 | 32 | 33.5 | 33.6 | 32 | 30.8 | 30.3 | 30.4 | 30.7 | 30.1 | 29.6 |

*Figure 11 – Quezon City Climate and Precipitation by Month (Climate-data.org)*

As indicated early, the population of Quezon City is 2,936,316 people as of the 2015 Census, with an annual growth rate of 2.42% (QCG, 2013). Approximately 20% of the population lives in District 2 in the northeast part of the city. This district is comprised of only 4 barangays – Commonwealth, Batasan Hills, Payatas and Holy Spirit. As seen in *Figure 12* this area also has a relatively high population density. In general, the largest population and population growth areas for the city are in the northern parts of the city.

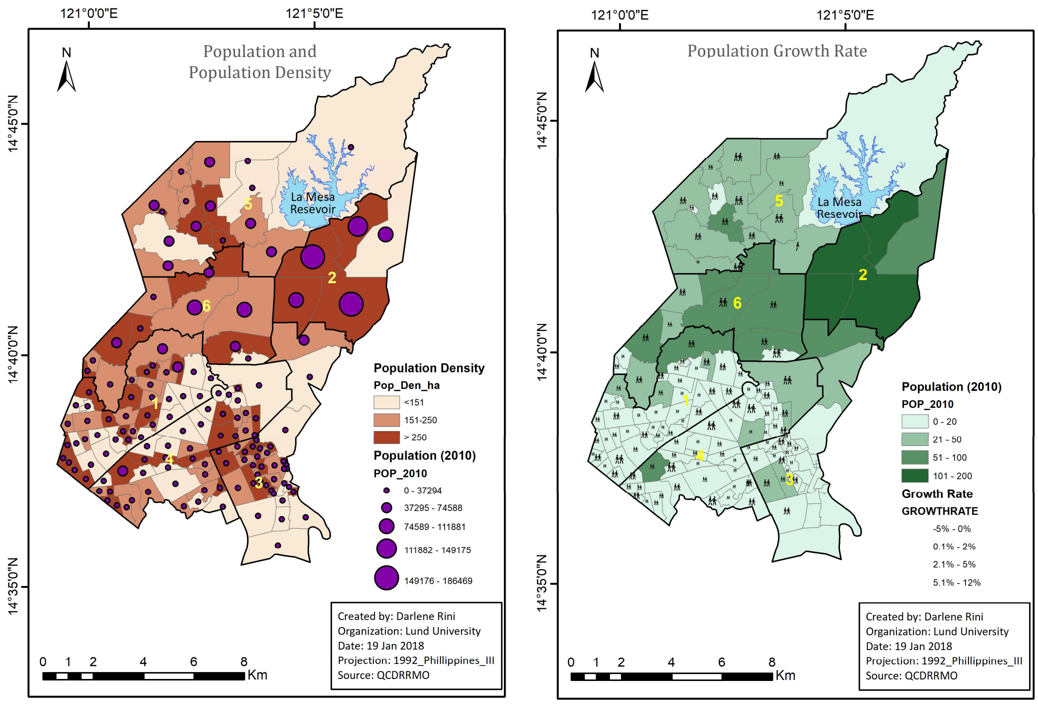



*Figure 12 – Population and population density per barangay and district (left). Population and population growth rate per barangay and district (right)*

Most residents are between the ages 15-65 (~70%) with the average at 24.3 years old. The senior population (65+ years) is ~4%, with young children (<10 years) is ~18%. See *Figure 13*

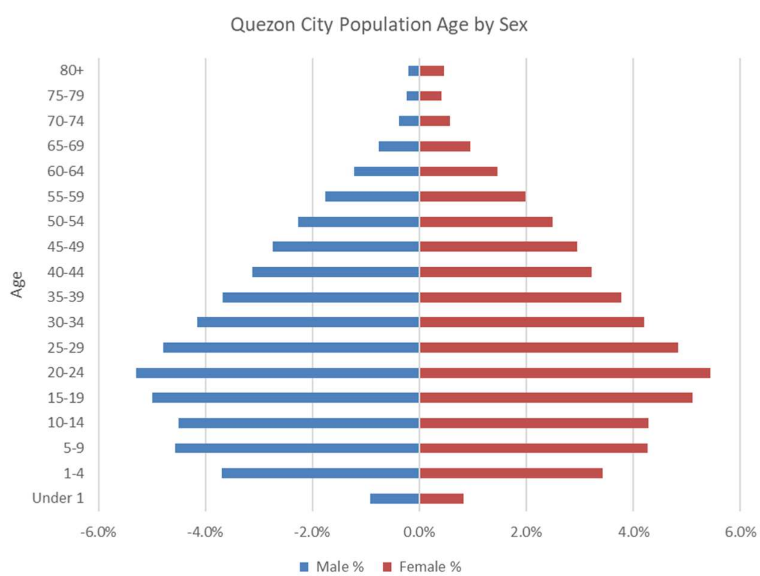



*Figure 13 – Population breakdown my age and by sex*

The literacy rate is estimated to be 99.74% (QCG, 2013) with 38% of the population achieving at least a high school degree, and 32% achieving some college education. *Figure 14*.

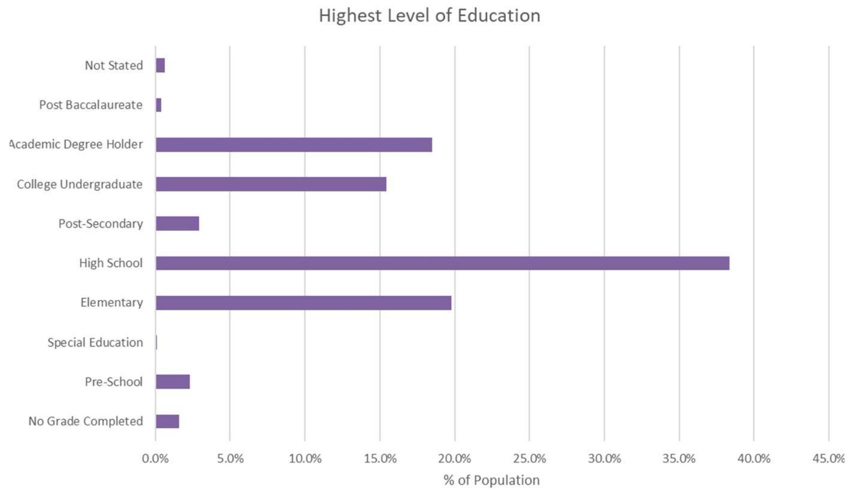



*Figure 14 – Highest education level achieved by residents*

## 6.2 INFORMAL SETTLEMENTS

QC is estimated to have the largest IS population in the NCR with nearly 30% of its population (~1 million), most of whom living in poverty of less than 8,403PHP or 168 USD per month (Morin et al, 2016). Figure 15 illustrates the IS areas across the city based on CPDO and UPAO records in 2010, as well as, the percentage of IS areas relative to the total barangay area. The total IS area is estimated to be 16.7 km$^2$ or 10.4% of total land area (48% more than the Assessor's records). Assuming a total IS population of 1 million inhabitants, the average IS population density is estimated to be 59,880 people/km$^2$ (598 people/ha), 3.4x more than the city average (17,759 people/km$^2$).

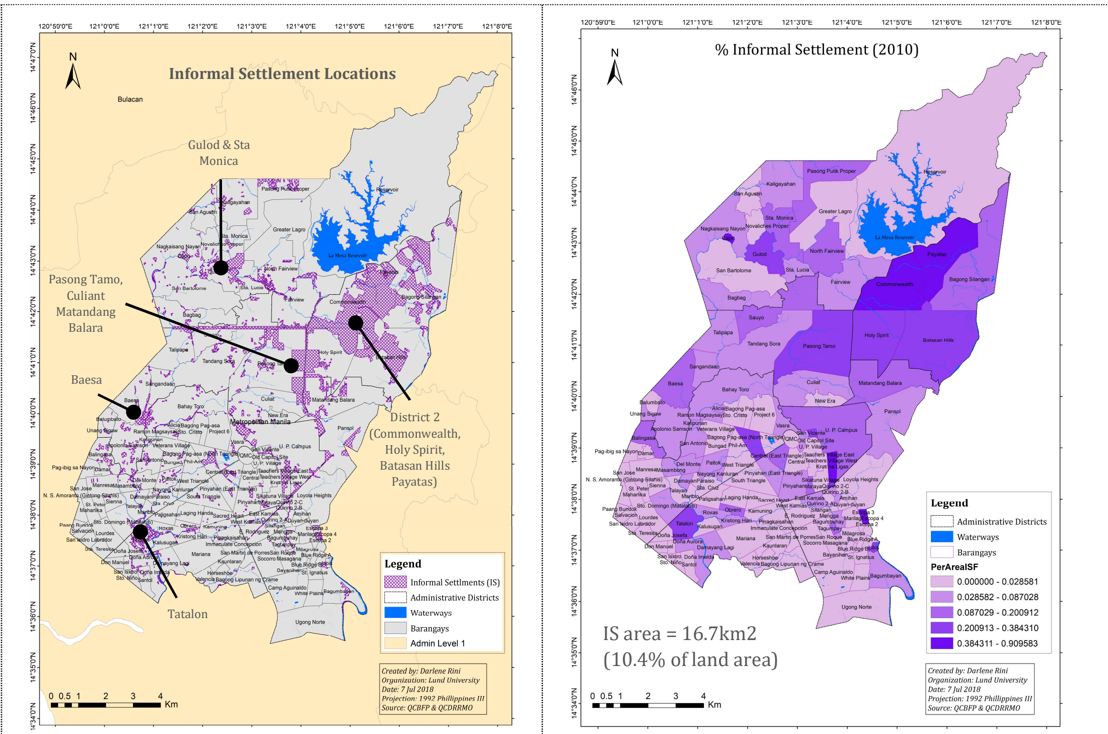



*Figure 15 – (Left)* IS locations across the city. (Right) Percentage area of ISs by barangay

While IS areas are dispersed across the city and are typically located along waterways, flood plains, seismic fault lines, and open dumpsites (See Figure 16), the highest concentrations are in District 2 (Figure 15) and other pockets distributed around the city (e.g. Capri, Tatalon, Krus na Ligas, North Triangle, Escopa, Gulod and Libis). A cursory review of media reports and BFP records highlight a number of these locations as sites of major IS fires in the past 10-15 years.

Refer to Annex C for additional details, descriptions and images of a field survey of over 100 buildings in two QC IS areas (Batasan Hills and Botocan), collected during two in-country visits in 2017-2018.

*Slums along waterway to Manila Bay*

*Figure 16 – Images of informal settlements located throughout QC along waterways, high risk areas, and open dumpsites (credit: Rappler).*

*Waterway along fault line*

*Payatas, QC*

## 6.3 RECENT INFORMAL SETTLEMENT FIRES

During an in-country field visit in 2018, two major fires occured in two separate ISs one week apart. One of these fires occurred on February 28, 2018 in Tatalon, while the other occurred on March 6, 2018 in Botocan. Both fires affected 1000s of people and damaged 100s of homes. The cost of direct damages and/or casualties were still under investigation at the time, but the estimated cost of relief assistance was in the 100,000s PHP. See Table 4 and Figure 17 – Figure 19 for a summary of fire impacts and aerial images of the fire sites.

*Table 7 – Two large informal settlement fires in Quezon City during 2nd field visit, plus additional major IS fires in recent years*

| Date | Location | No. of Affected Families | No. of Affected People | No. of Houses Damaged | Deaths | Injuries | Cost of Assistance | |
|---|---|---|---|---|---|---|---|---|
| 2018-02-28 | Tatalon | 407 | 2,035 | 100 | NR | NR | ₱ 690,152 | $13,803 |
| 2018-03-06 | Botocan | 478 | 2,390 | 150 | NR | NR | ₱ 481,686 | $9,633 |
| 2018-01-30 | Kamuning | 20 | 100 | 10 | 1 | 3 | NR | NR |
| 2018-01-18 | Old Balara | 300 | 1500 | 50 | NR | NR | NR | NR |
| 2017-08-11 | Talayan | 700 | 3500 | 300 | 1 | NR | NR | NR |
| 2016-12-27 | Pinyahan | 1000 | 5000 | 500 | | | | |
| 2011-04-11 | Culiat | 450 | 2000 | 150 | 1 | | ₱ 2,000,000 | $400,000 |

*Source: BFP-NCR*

*NR – Not reported at time of field visit*

*Figure 17 – Extent of fire damage in informal settlement fire in Botocan, Quezon City on March 6, 2016 (photo credit: QCDRRMO)*

*Figure 18 – Aerial photo of extent of damage of informal settlement fire in Botocan (photo credit: QCDRRMO)*

*Figure 19 – Aerial photo of extent of damage of informal settlement fire in Tatalon, February 28, 2018 (photo credit: QCDRRMO)*

# 7 Results and Analysis

The research conducted in this study, as outlined in the methodology (Section 4), was exploratory in nature due to the limited amount of data and previous works on IS fires in the Philippines. The analyses utilized both primary and secondary data, and although the studies are primarily quantitative in nature, the process of undertaking the work was also informed by qualitative inputs (i.e. interviews with key QCG officials, Barangay captains and local IS residents).

The results start by looking at basic fire statistics to get an overview of the current risk profile for fires in the Philippines, but more specifically in Quezon City. It evaluates data collected by the BFP, as well as, previous research on fires in other contexts as needed to gain perspective. While this data does not focus on specific IS fire issues (because BFP does not systematically or consistently collect this data), it is essential in understanding the significance of IS fires in the overall urban fire problem. Building on this baseline, the results of the geospatial analysis is presented to gain insight into IS influenced fire risk profile of Quezon City. Once this has been developed, the focus zooms out to look at how this increased fire knowledge can be incorporated into the existing urban disaster risk index method used in QC, as a basis for managing urban disasters more holistically.

## 7.1 STATISTICAL ANALYSIS

### 7.1.1 National and Regional Fire Statistics

To better understand the IS fire problem in QC, a top-down fire incident data analysis has been performed. At the national level, a total of 143,970 fires were reported between 2006-2017 (12-year period), with annual increases of 8,823 fires in 2006 to 14,197 in 2017 (averaging 11,998/yr). This trend could be a result of population increase, but as seen in Figure 20, the relationship in not exactly linear – the number of fires has risen 5%, on average annually, while population has risen by 2% (i.e. 86,777,399 in 2006 to 100,981,437 people in 2015).


*Figure 20 – Annual fire events and population in the Philippines from 2006-2017 (PSA)*

During this period, fires resulted in approximately 3,081 deaths and 12,312 injuries for an average of 257 deaths and 1,026 injuries per year. See Figure 21. As was discussed and shown in Figure 4 and Table 5 in the introduction, the number of fire deaths per year are relatively high, second highest threat when compared to other major hazards of concern in the Philippines (e.g. earthquakes, flooding, typhoons). However, when compared to other nations, the Philippines has a death/100k people rate of 0.268, whereas rates in other developed countries are notably higher. See Table 8

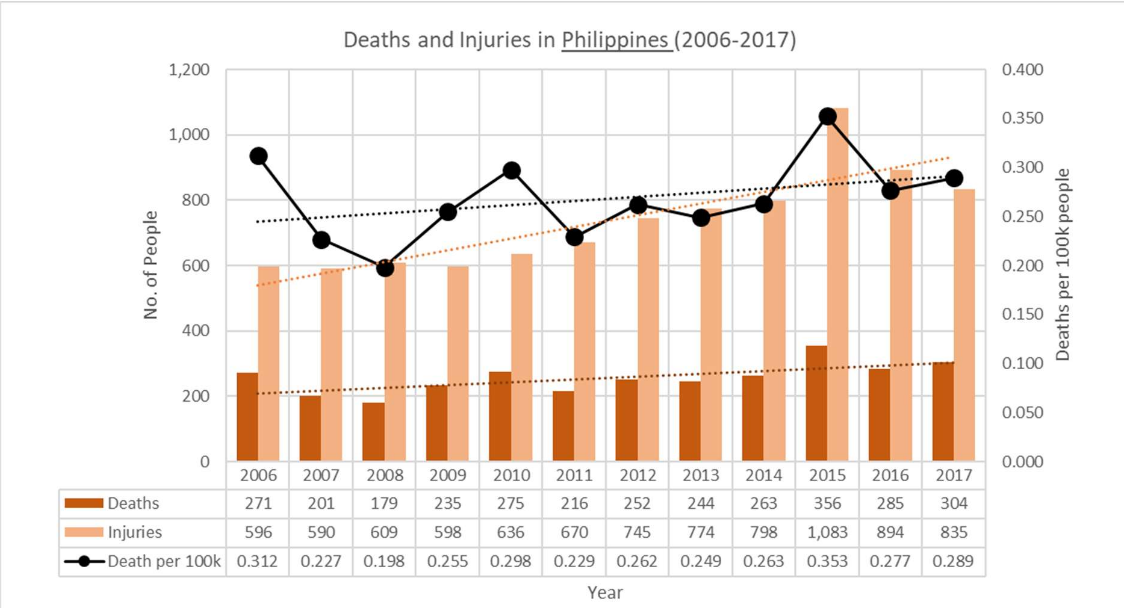



*Figure 21 - Number of annual deaths and injuries in the Philippines from 2006-2017 (PSA)*

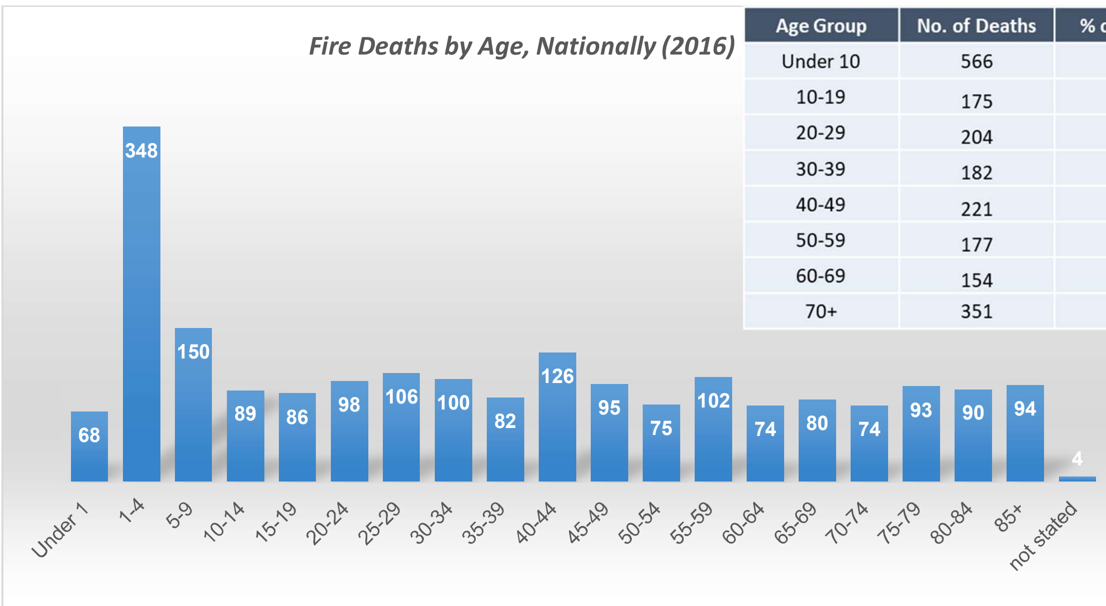
*Table 8 – Comparison of number of annual fires deaths per 100k inhabitants internationally*

| Country | Fires Deaths/100k inhabitants | Fires Deaths/100 fires |
|---|---|---|
| Philippines | 0.268 | 2.25 |
| Russia | 7.50 | 6.9 |
| South Africa | 4.91** | - |
| India | 1.60 | - |
| Finland | 1.30 | 0.6 |
| Japan | 1.30 | 3.7 |
| U.S. | 1.00 | 0.2 |
| United Kingdom | 0.60 | 0.2 |
| France | 0.50 | 0.1 |
| Sweden | 1.00 | 0.4 |
| Singapore | 0.10 | 0.1 |
| Switzerland | 0.20 | - |
| Global Average* | 1.90 | 0.8 |

***Source: World Fire Statistis Center (2011-2015) (Brushlinsky, 2017)***
****Representing 39 avg countries reporting every year since 1993. Most countries are in the developed world.***
*****Taken from world life expectancy***

While the fire death rates (by population) in the Philippines are generally lower than most other reporting countries, determining whether this difference is due to the number of fires experienced in each country or if the fires experienced in one country are deadlier than those of another, will require further investigation. That said, a cursory review of the death rate per 100 fires in the Philippines, was approximated to be 2.254 per 100 fires, while in the U.S. it is estimated to be 0.2, suggesting that fire severity per incident is worse in the Philippines. (Brushlinsky, 2017).

Some of this increased fire severity per incident could be related to the demographics of the exposed populations. Figure 22 illustrates the distribution of deaths by age for all fire incidents nationally in 2016. As seen, most fire victims appear to be young children (below the age of 10) and seniors (above 70 years), i.e. members of society most vulnerable to threats such as fire. Looking at the age dependency ratio of the Philippines (57.6) compared to the U.S. (51.65) (Singh, 2016; Global Economy, 2015), the Philippines has a slightly higher ratio (on average) which may explain in part the higher fire death rate per fire incident as there are fewer caretakers to assist more vulnerable members during emergencies.




| Age Group | No. of Deaths | % of Deaths |
|---|---|---|
| Under 10 | 566 | 28% |
| 10-19 | 175 | 9% |
| 20-29 | 204 | 10% |
| 30-39 | 182 | 9% |
| 40-49 | 221 | 11% |
| 50-59 | 177 | 9% |
| 60-69 | 154 | 8% |
| 70+ | 351 | 17% |

*Figure 22 – National fire deaths by age from 2006-2017 (data from PSA, 2016)*

With respect to financial losses, fire damages resulted in approximately $700 million dollars between 2010 – 2017, with an annual loss rate of $87 million/year (See Figure 23). These economic losses seem significant but when compared to the national GDP ($246 billion annual average), they represent only 0.02-0.04%, and when compared to typhoon losses by GDP (0.39%), they are 1/10th lower. However, comparing fire losses to other “popular” hazards as was shown in Figure 5, fires still play a relatively significant roles as the 2$^{nd}$ largest cause of financial losses from hazard events. Note: Further research should assess ranking of hazards from a probabilistic perspective to compare equivalent annual impacts. In this view, fires will likely still be in the top 5.

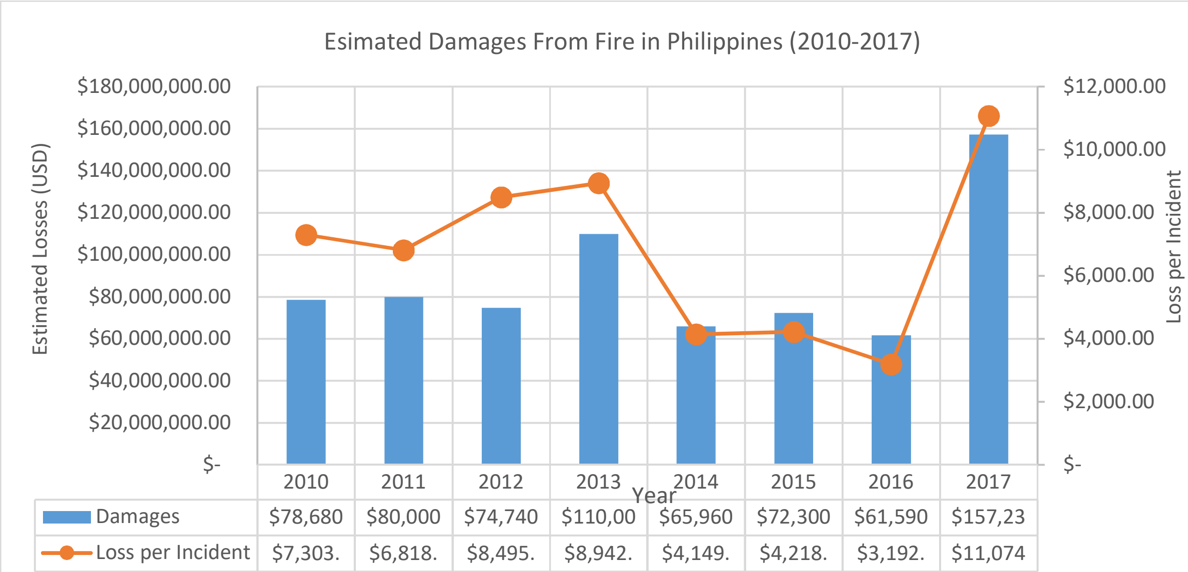



*Figure 23 - Estimated annual damages and loss per fire incident in the Philippines from 2006-2017 (data from PSA, 2006-2017)*

At the regional level (i.e. Metro Manila), the number of fire incidents, over the same 12-year period (2006-2017), totaled to 47,382 and increased annually from 3,665 fires in 2006 to 4,645 in 2017 (averaging 3,948/year). See Figure 24. Like the trends at the national level, fire incidents have risen 3%, on average annually, while population has only risen by 2% in the same period (i.e. 11,432,479 people in 2006 to 12,877,253 people in 2015).

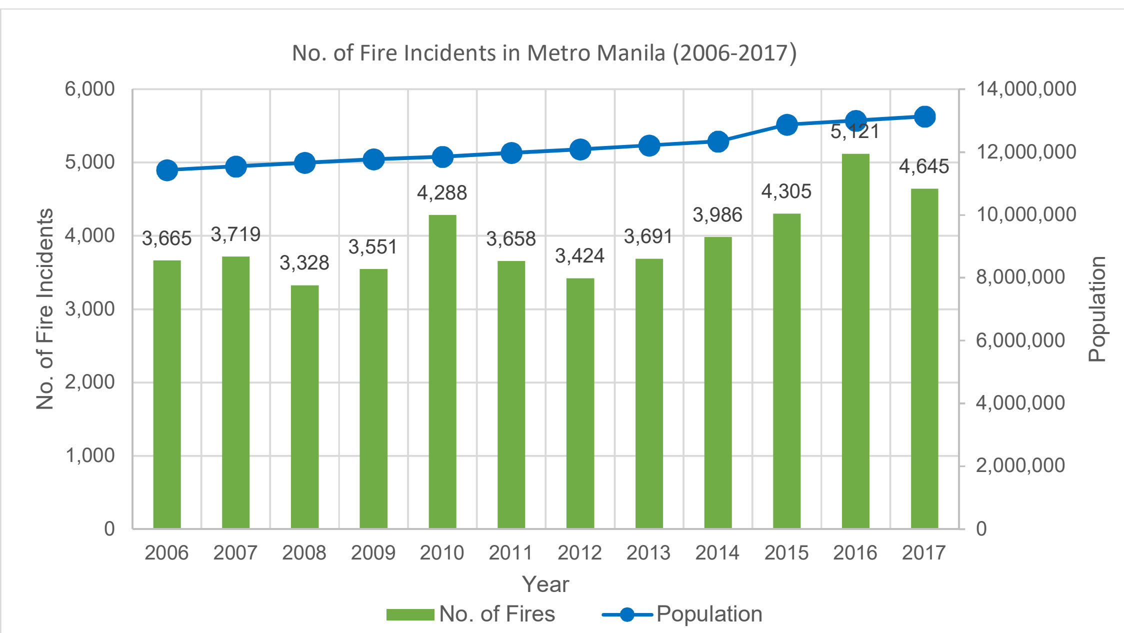
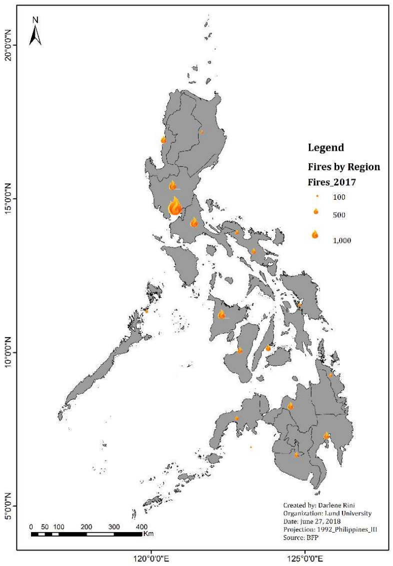



*Figure 24 – Annual fire events and population in Metro Manila from 2006-2017 (PSA)*

The number of incidents in the NCR account for the largest percentage of national figures (i.e. 33%). See *Figure 25*. This high percentage could be due to the larger population in the NCR, but as seen in the figure, the NCR population is only 12% of the national total. All other regions fire incident rate appears to align with % population. This is significant as it indicates that the NCR has a higher rate of fire exposure by population (i.e. 2.75x greater compared to the average).




| Region | No. of Fires (2016) | % of Total Fires | Population | % of Total Pop |
|---|---|---|---|---|
| NCR | 4645 | 33% | 12,877,253 | 12% |
| R1 | 754 | 5% | 5,026,128 | 5% |
| R2 | 179 | 1% | 3,451,410 | 3% |
| R3 | 1258 | 9% | 11,218,177 | 11% |
| R4A | 1334 | 9% | 14,414,774 | 14% |
| R4B | 205 | 1% | 2,963,360 | 3% |
| R5 | 429 | 3% | 5,796,989 | 6% |
| R6 | 1243 | 9% | 7,536,247 | 7% |
| R7 | 622 | 4% | 7,396,903 | 7% |
| R8 | 202 | 1% | 4,440,150 | 4% |
| R9 | 282 | 2% | 3,629,783 | 3% |
| R10 | 754 | 5% | 4,689,302 | 4% |
| R11 | 760 | 5% | 4,893,318 | 5% |
| R12 | 348 | 2% | 4,545,276 | 4% |
| CARAGA | 252 | 2% | 2,596,709 | 2% |
| CAR | 289 | 2% | 1,722,006 | 2% |
| ARMM | 67 | 0% | 3,781,387 | 4% |
| NIR | 574 | 4% | 4,414,131 | 4% |
| Total = | 14,197 | | 105,393,303 | |

*Figure 25 - No of fires incidents by region, compared to the national fire and population totals*

Looking at the casualties, the NCR experienced approximately 914 deaths and 3,105 injuries during 2006-2017, with annual averages of 76 deaths and 266 injuries, respectively. See Figure 26. Compared to the national figures (Figure 21), trends in deaths, injuries and death/population in the NCR appear to be increasing at a greater rate. The average death/100k inhabitants in NCR is 0.691 compared to the national average of 0.268 (i.e. 2.57x more likely to die from fire in the NCR compared to the rest of the nation). Of note, however, is the lower death rate per 100 fires, where the NCR region has an annual average of 1.93 compared to the national average of 2.25. The increased fire frequency and fire death risk in the NCR could be indicative of effects of urbanization (i.e. higher concentration of people introducing more ignition sources and exposure). Likewise, the positives of urbanization (i.e. increased fire safety knowledge/resources) could also explain the conversely lower per fire death risk compared nationally.

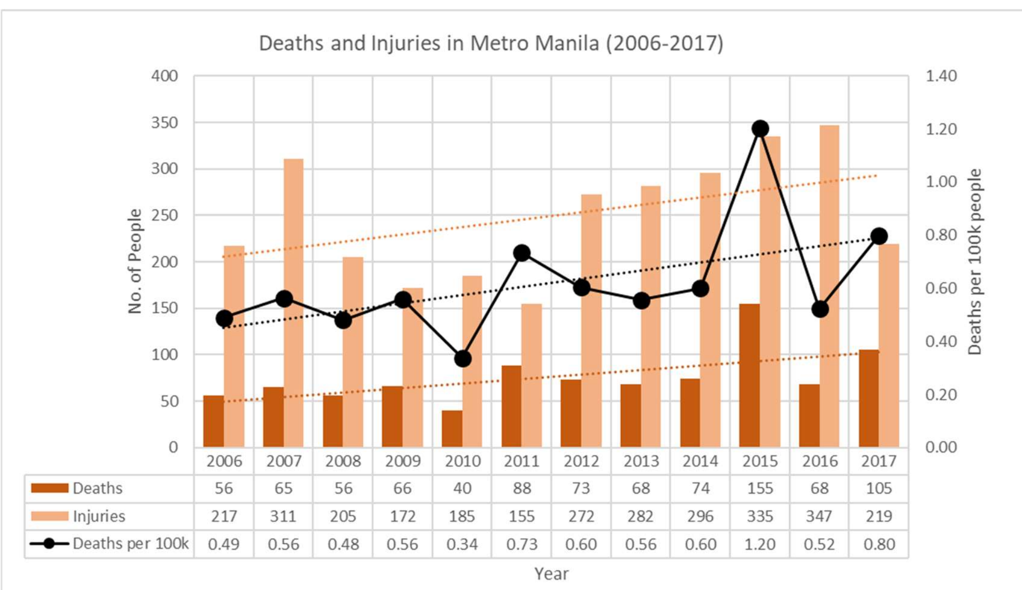



*Figure 26 - Number of annual fire deaths and injuries in Metro Manila from 2006-2017 (PSA)*

### 7.1.2 Quezon City Fire Statistics

Given the baseline of general fire statistics at the national and regionally level, this section assesses fire statistics at the city-level in QC, as well as, explores the role of ISs in this landscape given the available data.

At the city-level, fire incidents over the same 12-year period (2006-2017), totaled 7,706 with annual increases from 127 fires in 2006 to 1,049 in 2017 (averaging 968/year excluding data prior to 2010). See Figure 27. This equates to 80.3 fires/month or 2.6 fires/day or 6 fires/1km$^2$/year. This is a significant number of fires threating the urban population and consuming fire emergency and other city resources, in an already resourced-constrained society. *Note: As the data prior to 2010 was collected inconsistently, as seen in* Figure 27*, it has been excluded from the analysis.*

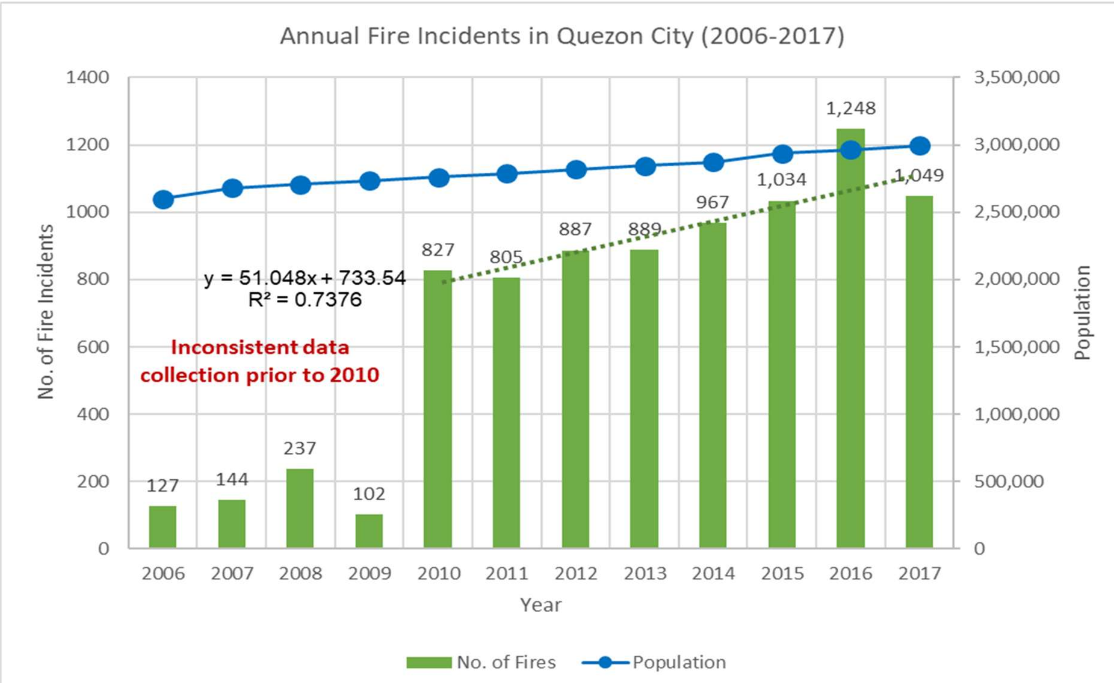



*Figure 27 – Annual fire incidents and population in Quezon City from 2006-2017 (PSA)*

Like trends at the national and NCR level, fires in the city have risen 4%, on average annually, while population has only risen by an average annual rate of 1.3% (i.e. 2,761,720 in 2010 to 2,936,116 people in 2015). This equates to an increasing trend in number of fires by population of 3% annual average.

With respect to life safety impacts, fires in QC resulted in approximately 99 deaths and 450 injuries for an average of 12 deaths and 56 injuries per year. This is approximately 21% of the NCR causalities which is consistent with QC's population proportion. See Figure 28. Like Metro Manila, QC's average annual fire deaths/100k inhabitants (i.e. fire death risk) is greater than the national average (0.4 vs 0.268). However, like NCR, QC's fire death rate per 100 fires (i.e. severe fire ratio) is also lower compared to the national (1.3 vs 2.25). Similar trends are observed for injuries. See ***Table 9***

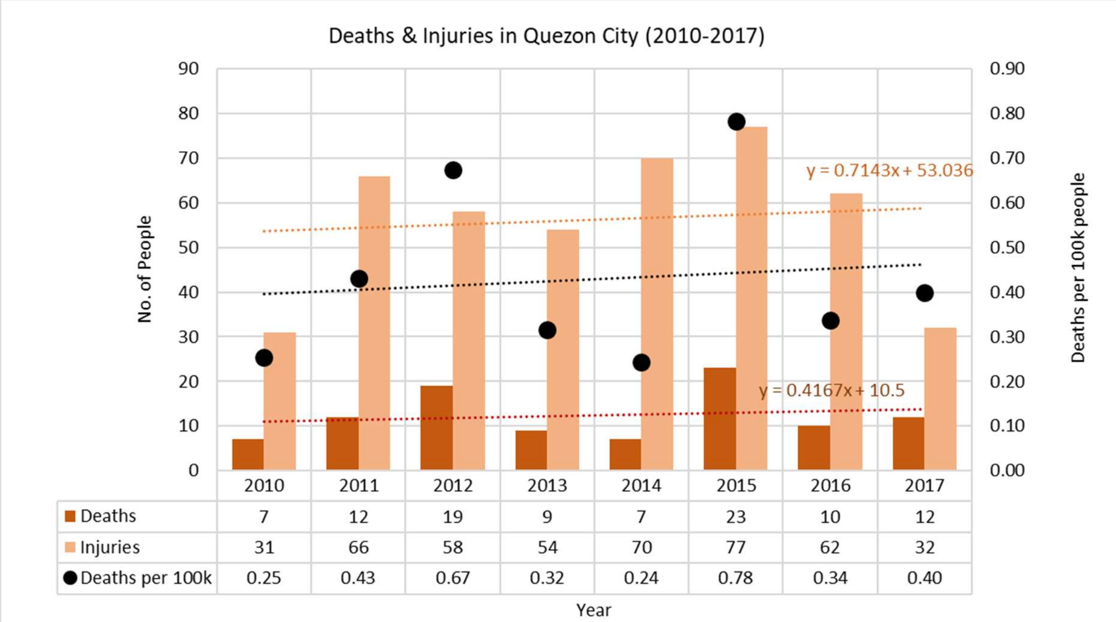



*Figure 28 - Number of annual fire deaths and injuries in Quezon City from 2010-2017 (BFP)*

*Table 9 – Comparison of fires deaths per 100k inhabitants and per 100 fires in Philippines*

| Administration Level | Fire Deaths/100k inhabitants | Fire Deaths/100 fires | Fires Injuries /100k inhabitants | Fire Injuries/100 fires |
|---|---|---|---|---|
| Philippines Nationally | 0.268 | 2.25 | 0.76 | 6.39 |
| Metro Manila (NCR) | 0.691 | 1.93 | 2.05 | 6.34 |
| Quezon City | 0.4 | 1.30 | 1.96 | 5.91 |

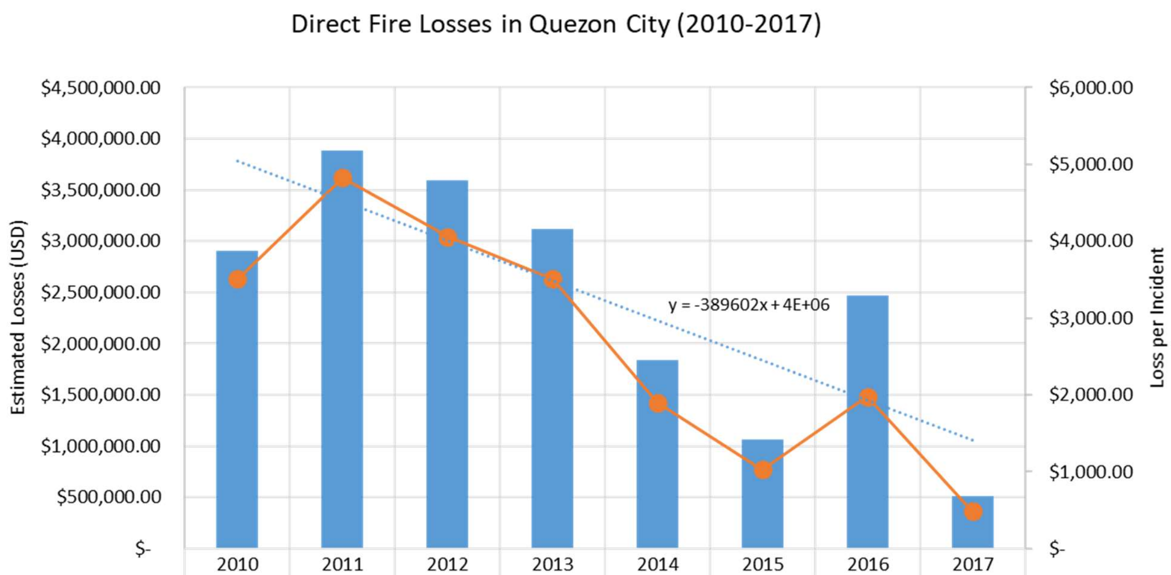
In comparison to other major cities in the world, fire death risk (by population) is similar in Hong Kong and/New York; while for severity of fires with respect to death rate/fire, QC and Metro Manila are an order of magnitude greater than other western cities (***Table 10***). With respect to injuries, there appears to be more fire injury risk by population, but similar with respect to injury rate per fire. While this comparison provides some perspective, it is difficult to draw hard conclusions as data collection methods, fire reporting systems, population reporting behaviors are likely inconsistent across countries.

*Table 10 – Comparison of fires deaths per 100k inhabitants and per 100 fires, cities globally*

| Administration Level | Fire Deaths/100k inhabitants | Fire Deaths/100 fires | Fires Injuries /100k inhabitants | Fire Injuries/100 fires |
|---|---|---|---|---|
| Metro Manila (NCR) | 0.691 | 1.93 | 2.05 | 6.34 |
| Quezon City | 0.4 | 1.30 | 1.96 | 5.91 |
| Delhi | 1.9 | 1.30 | 11.7 | 7.7 |
| New York City | 0.7 | 0.10 | 12.9 | 2.4 |
| Hong Kong | 0.3 | 0.1 | 4.5 | 0.9 |

***Source: World Fire Statistis Center (2011-2015) (Brushlinsky, 2017)***

With respect to estimated financial losses, fire damages resulted in approximately $19,376,585 million dollars between 2010 – 2017, with an annual loss rate of $2.4 million/year (See *Figure 29*). When compared to city GDP ($312 million annual average), the losses represent only 1% of GDP, which is 100x greater than the ratio of national fire losses to national GDP mentioned previously. If compared to the total DRM expenditure for QC (which is required to be 5% of the annual GDP by local DILG Memorandum Circular No. 2012- 73), then fire losses represent 15% of that budget ($2.4 mil/$15.6 mil) (QCDRRMO, 2013/2). One could infer that the high ratio of fire losses to GDP and/or social expenditures, compared to the same ratio at the national level, is due to a higher concentration of resources/wealth in the capital region exposed to fire hazards and/or higher fire frequency. Similar trends in economic losses for wealthier areas are also observed internationally, as was discussed in the introduction. That said, the annual losses since 2010 appear to be reducing, which may reflect increasing DRM interventions by QCG since Executive Order No. 23 Series of 2010 (QCDRRMO, 2013/2).




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| Damages | $2,901,31 | $3,887,03 | $3,596,47 | $3,116,23 | $1,836,38 | $1,062,54 | $2,468,41 | $508,192. |
| Loss per Incident | $3,508.23 | $4,828.61 | $4,054.65 | $3,505.33 | $1,899.05 | $1,027.61 | $1,977.90 | $484.45 |

Year

*Figure 29 - Estimated annual damages and loss per fire incident in QC from 2010-2017 (BFP)*

Looking at the breakdown of fire nature in Figure 30, most fires between 2013-2017 were non-structural (i.e. grass, rubbish, vegetation, utilities) in nature at 62%, while structural fires comprised 31% and vehicular fires (automobile, train, ship, etc.), 7%. Of the non-structural fires, electrical distribution and/or electrical post fires comprised the largest portion of this typology at 72% (or 45% of all fires in the city), followed by rubbish or trash fires at 15%.

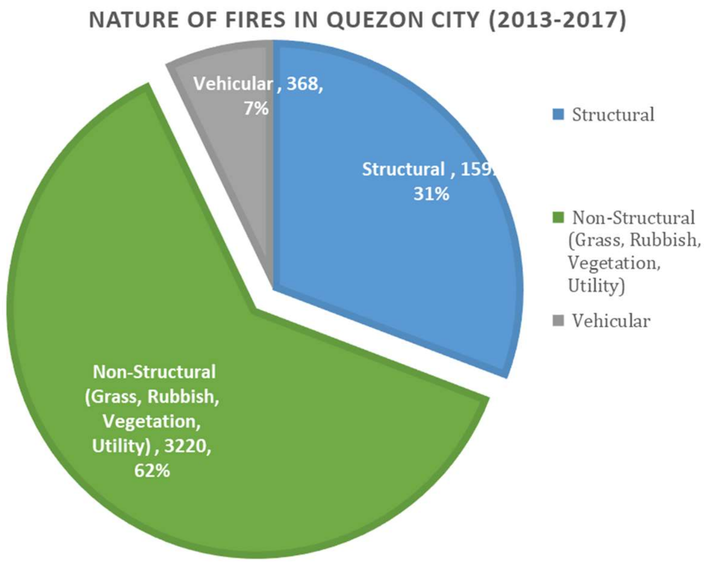



*Figure 30 - Distribution of fire incidents by nature of fire (2013-2017)*

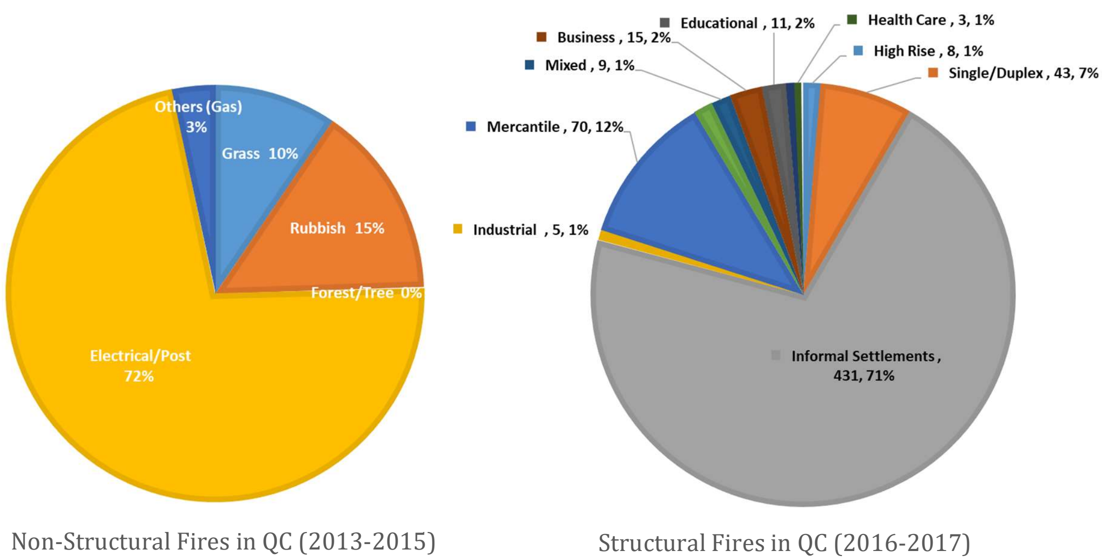



*Figure 31 - Distribution of <u>non-structural fires</u> (2013-2017) and <u>structural</u> fire incidents (2016-2017)*

As seen in Figure 31, all residential uses (IS, single/duplex and high-rises) make-up 79% of structural fires followed by mercantile (12%) and then business (2%). The high percentage of structural fires being residential in nature is consistent with national and NCR breakdowns, as well as, fire statistics from other cities internationally. Of major significance, however, is the large percentage of residential fires in QC occurring in IS areas at 89% (accounting for 71% of all structural fires for the city). With respect to all fires in the city, IS fires account for 22% of the entire fire risk landscape – signifying an area of great concern. Note: While the fire statistics data only had IS fire data collected for 2 years (2016-2017), it is anticipated that other years have similar breakdowns. This was explored in the GIS analyses in the following sections.

To evaluate the causes of fires and identify any unique issues with IS areas, a clustered bar chart was created comparing ignition sources at the city-level and within IS areas only. From Figure 32, fires city-wide appear to be predominantly caused by some electrical source (wiring, appliances, machinery) at 67% of the total. In addition to electrical sources, lighted cigarette butts make up the next largest source at 17%.

In IS areas, however, sources of ignition go beyond electrical wiring (47%) and electrical appliances (12%). Other significant ignition sources include open flame unattended cooking/stove (17%), as well as, open flame due to unattended candles (13%). All four sources of ignition in IS areas can be grouped under issues related to energy poverty (i.e. lack of access to legal and safe sources of energy) and behavioral patterns (e.g. leaving open flames unattended, leaving electrical appliances plug in when not in use, overloading electrical connections). While electrical wiring is the source of nearly 50% of all IS fires, it is interesting to note that in conversations with local officials and IS residents the focus of attention was on illegal electrical connections (i.e. "jumpers" See *Figure 33*), as opposed to, the other two sources related to open flames. Note: Unfortunately, it is not possible to ascertain if all electrical wiring causes were due to "jumping" or from other sources such as overloading of circuits.

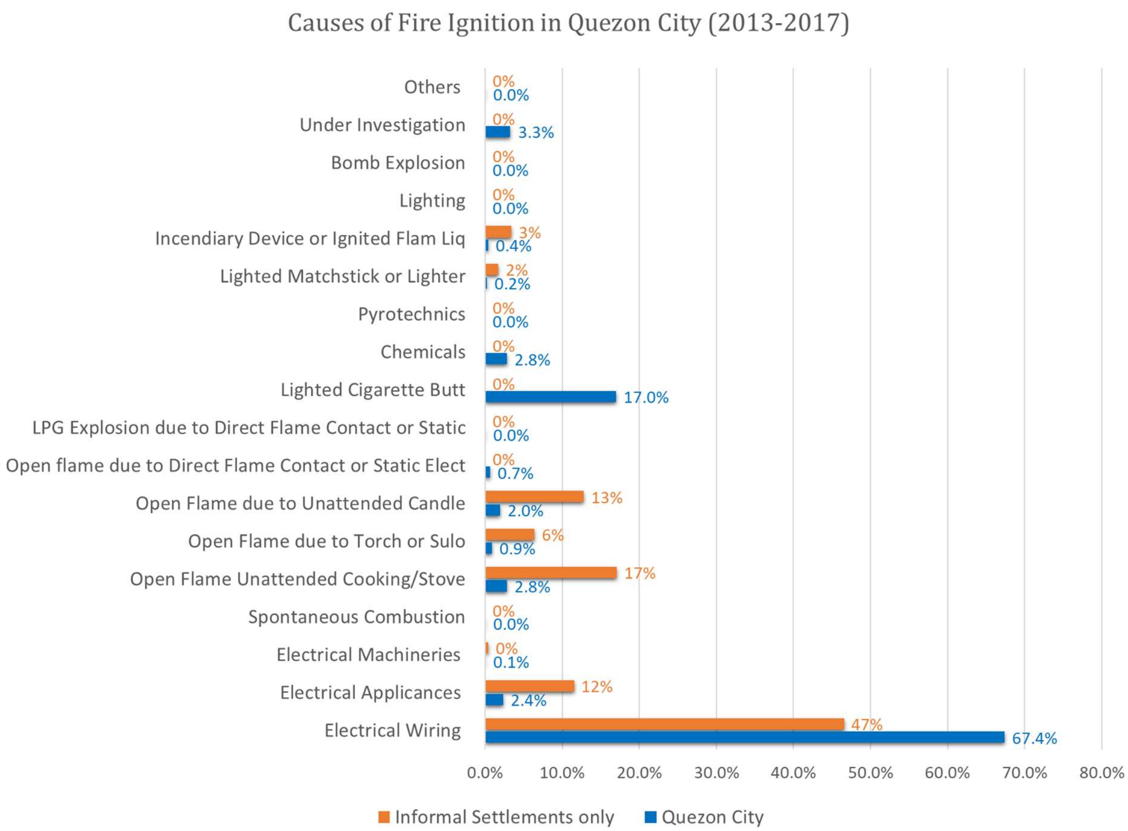



*Figure 32 – Cause of ignition for all QC fires and IS area fires only from 2013-2015 (PSA)*

*Figure 33 - Illegal electrical connections ("jumpers") is a common issue in Quezon City. (credit: REUTERS/Erik De Castro*

To gain additional insight into the cause of fires, several spider diagrams have been plotted to observe temporal patterns in fire incidents. In *Figure 34*, the percentage of fires by month is plotted, and reveals that most fire incidents occur during March and April – the hot, dry season in the Manila. Comparing this with the number of electrical ignitions by month (*Figure 35*), it can be observed that electrically caused fires also occur during the summer periods. This correlation can be due to the increased usage of air conditioning and electric fans, leading to electrical overloads and/or electrical shorts. This was observed in the second field visit in March 2018 and in discussions with local QCG officials.

As also seen in *Figure 35*, fires initiated by lighted cigarettes also predominantly occurred during March – the hot dry season. This is likely due to this time of year being extremely dry, such that a discarded lite cigarette would be more likely to catch dry rubbish and/or vegetation. One observes that there are essentially no fires caused by cigarettes between June through December, as the peak rainy season and precipitation levels are the highest between June-October, and the shoulder months in May, November and December (refer to *Figure 11*).

With respect to the time-of-day, *Figure 36* illustrates that most fires occur between 9:00 and 21:00, with a peak occurring around 18:00 when most people are awake and likely cooking and/or doing other activities at home.

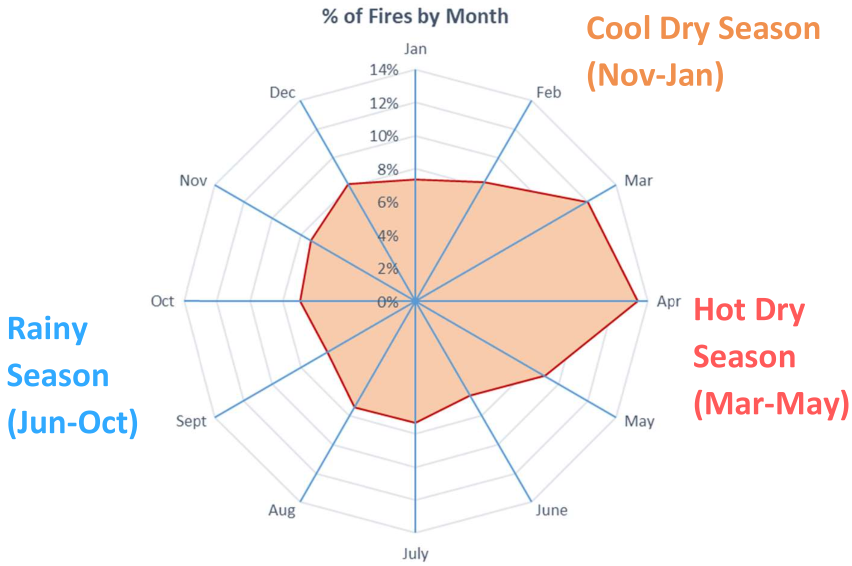



*Figure 34 – Percentage of Fires Incidents and Number of Electrical Ignitions by Month*

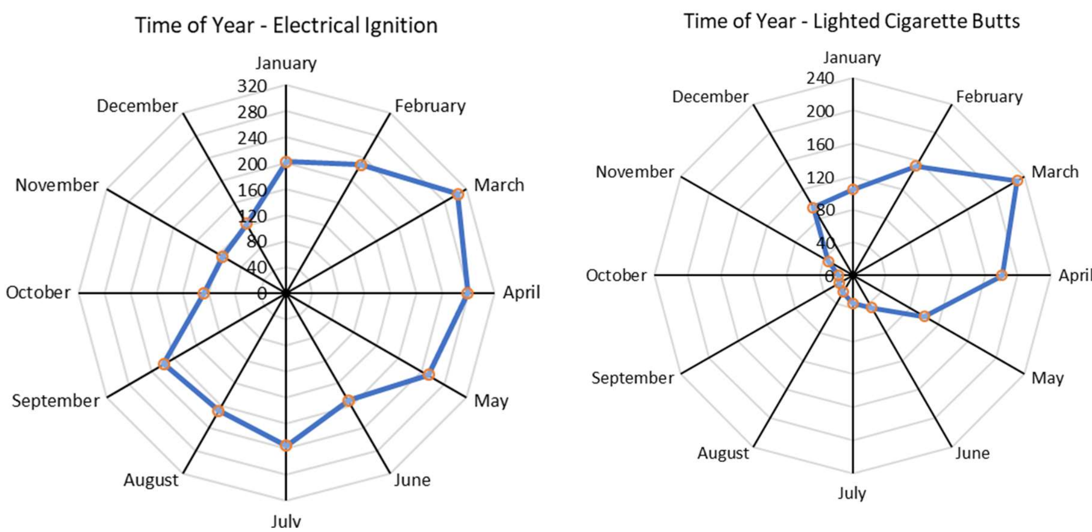



*Figure 35 –Number of Electrical Ignitions and Lighted Cigarettes by Month*

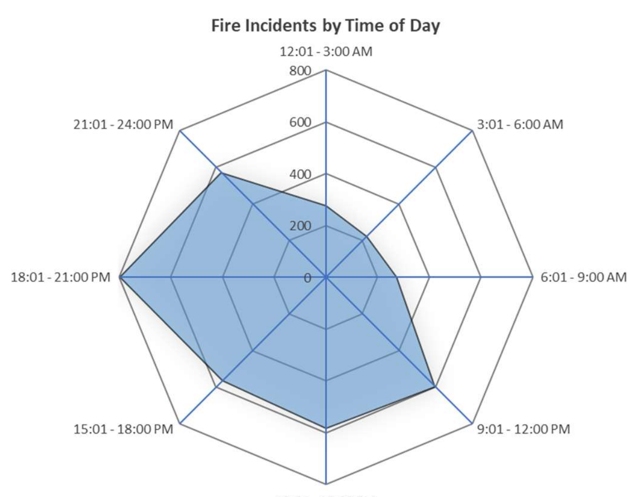



*Figure 36 –Number of fire incidents in QC by time-of-day*

Evaluating fire typology and time-of-occurrence in *Figure 37*, most structural (including IS structures) and non-structural fires appear to occur during the main fire occurrence times (i.e. 12:00-18:00) when people are awake and active (possibly cooking, using appliances, etc.). Vehicle fires, on the other hand, appear to occur regularly throughout the day with lower rates in the early morning and near lunch time, when fewer people are driving.

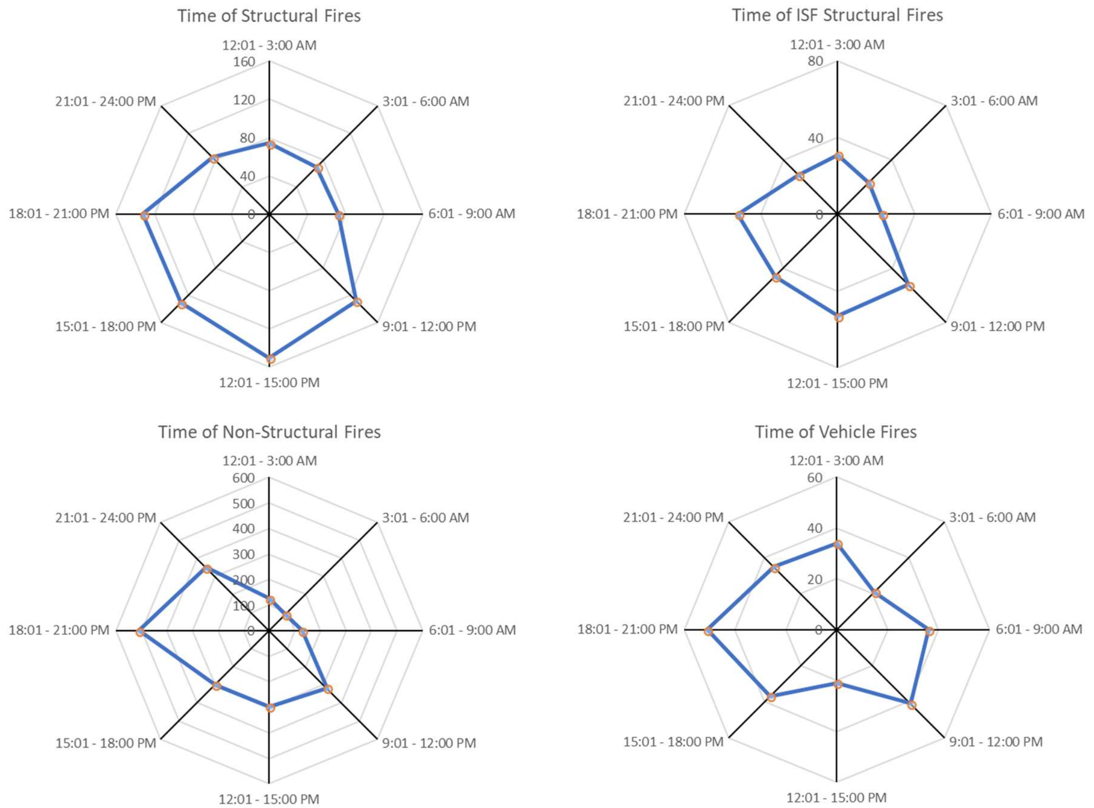



*Figure 37 – Time-of-day of fires by typology (structural, non-structural, IS structures & vehicular)*

As shown in *Figure 37*, most IS fires occur between 9:00 and 18:00. This is likely due the large percentage of IS dwellers undertaking jobs from within their homes (i.e. homemakers, vending, and other unskilled work at home), as well as, some house members being retired (Singh, 2017). The breakdown of causes of fires in IS dwellings are shown in *Figure 38*, also reflects the live/work nature of the IS communities with most causes occurring during the typical working day. However, there are larger incidences of electrical fires and unattended candle fires occurring between 18:00-21:00, when natural lighting levels are low requiring electrical and/or candle light.

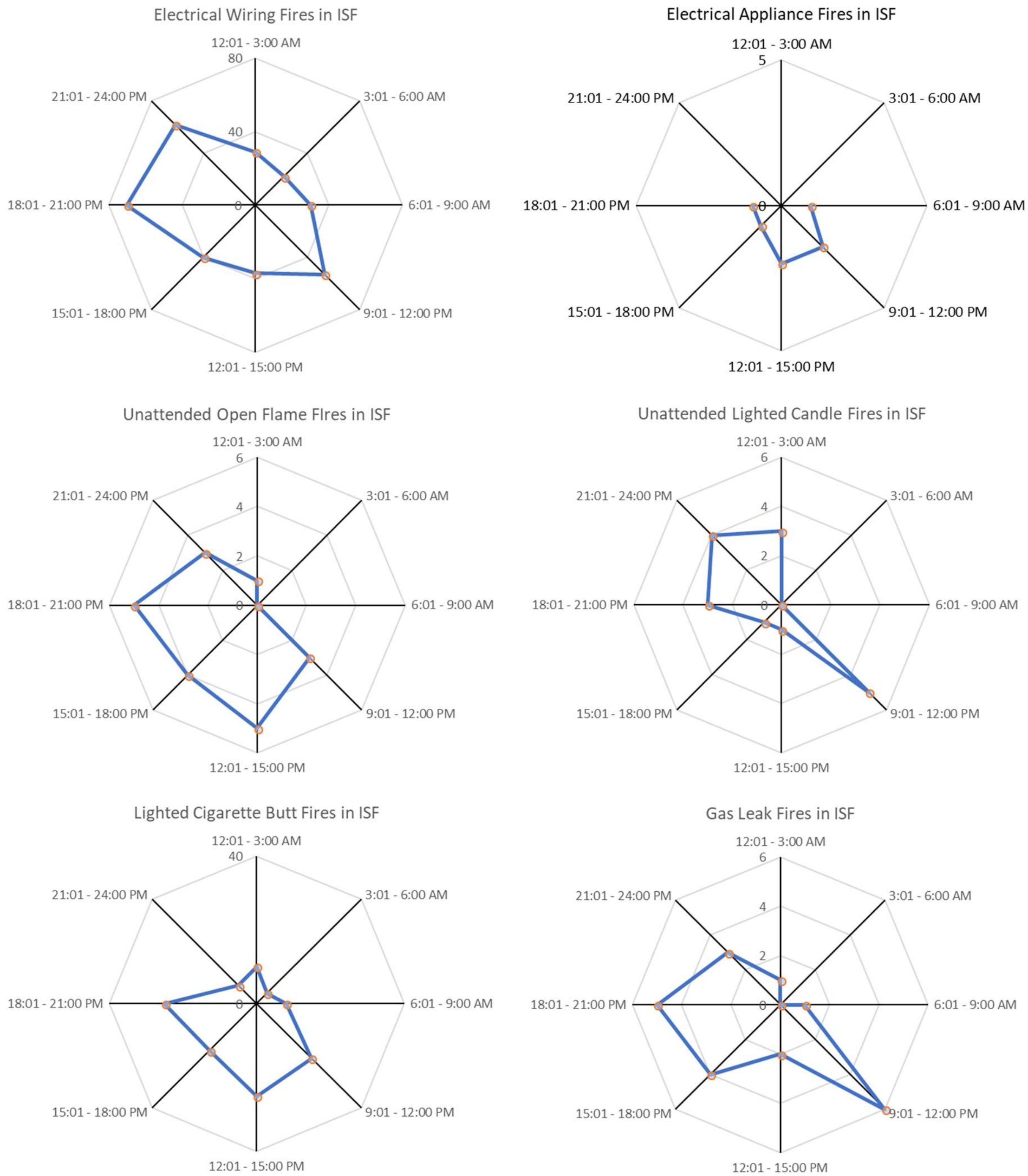



*Figure 38 – Time-of-day of fires in IS areas by ignition source*

## 7.2 GEOSPATIAL ANALYSIS AND MAPPING

Building on the fire statistics in Section 7.1, this section presents the results of several geospatial analyses described in the methodology. This analysis was key to assessing IS fire characteristics as current fire data collection in QC do not consistently code for IS location but do record incident address.

Note: As previously mentioned, the fire data collection system for QC prior to 2010 was inconsistent and thus only fire data between 2010-2017 has been considered. Other data inconsistencies were also observed for the BFP data. See Annex D.2 for details, along with some maps of all fire incidents during the study period.

### 7.2.1 Descriptive Informal Settlement Fire Statistics

As summarized in Table 11, between 2010-2017 there were 1,580 fires in ISs, which comprised 23% of all fires in QC. While IS fires appear to comprise similar percentages of all fire typologies to the total, most of the IS fires (52% = 817/1580) are non-structural in nature, while 35% involve structures. This appears consistent with the general breakdown of non-structural to structural fire ratio from the fire statistics analysis (Section 7.1.2).

*Table 11 - Breakdown of fire incidents by type, description and % of total fire events*

| Fire Type | Description | No. of Incidents | % of Incidents | No. in IS Areas | % IS by Fire Type |
|---|---|---|---|---|---|
| Structural | Buildings | 1,832 | 28% | 567 | 31% |
| Non-Structural | Rubbish, Vegetation, Post, Gas, Others | 4,289 | 58% | 817 | 22% |
| Vehicular | Car, Ship, Airplane | 471 | 6% | 61 | 15% |
| Not-Coded | | 513 | 8% | 135 | 26% |
| Total | | ***6,841*** | | ***1,580*** | ***23%*** |

To evaluate temporal patterns, the number of IS fires by year and by percentage of the total fire count per year were plotted. As seen in Figure 39, there is a general increase in both number of IS fires (+ 10%) and % of IS fires (+3%) between 2010-2017. As population data and sizes of IS areas are not tracked by census data, it is unclear if the trends are associated with IS population increases/decreases or other physical or socio-economic factors. Note: the last accounting of the IS areas was in 2010. In any event, in absolute terms the IS fire problem is growing (in numbers and %).

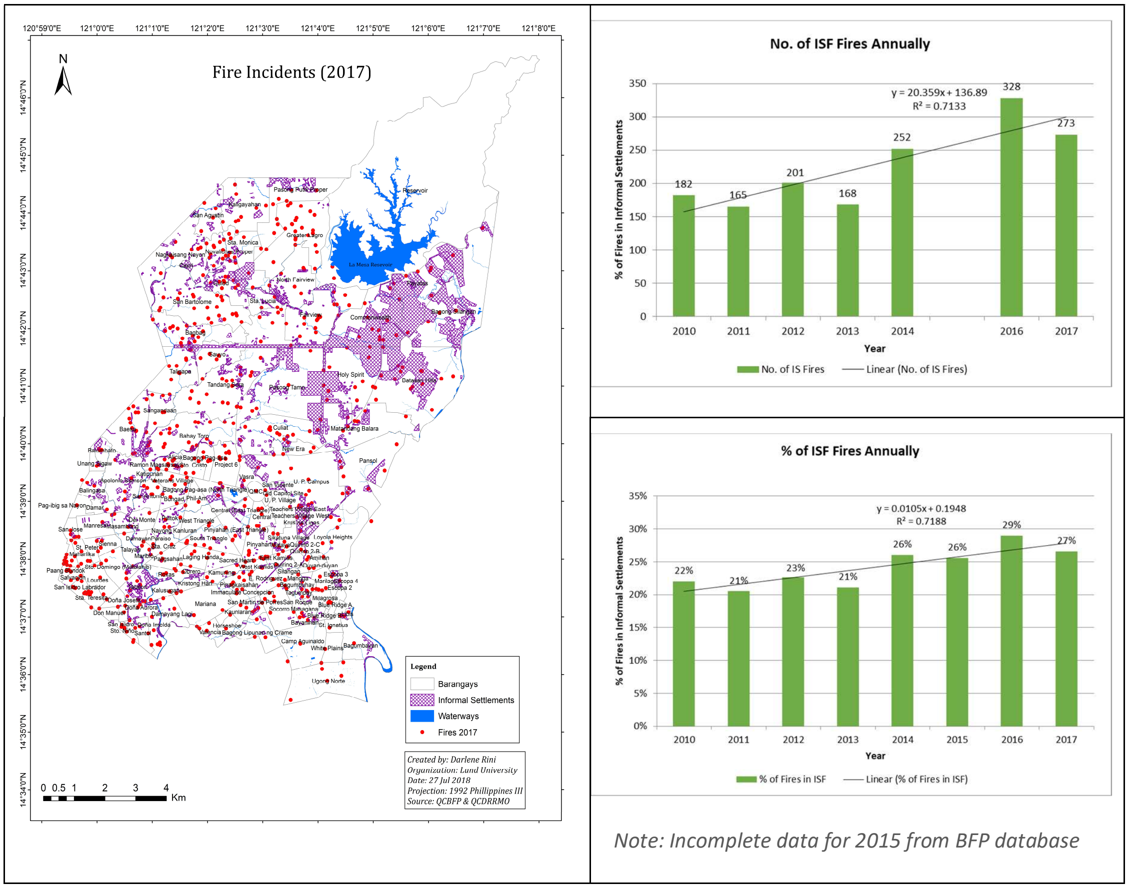
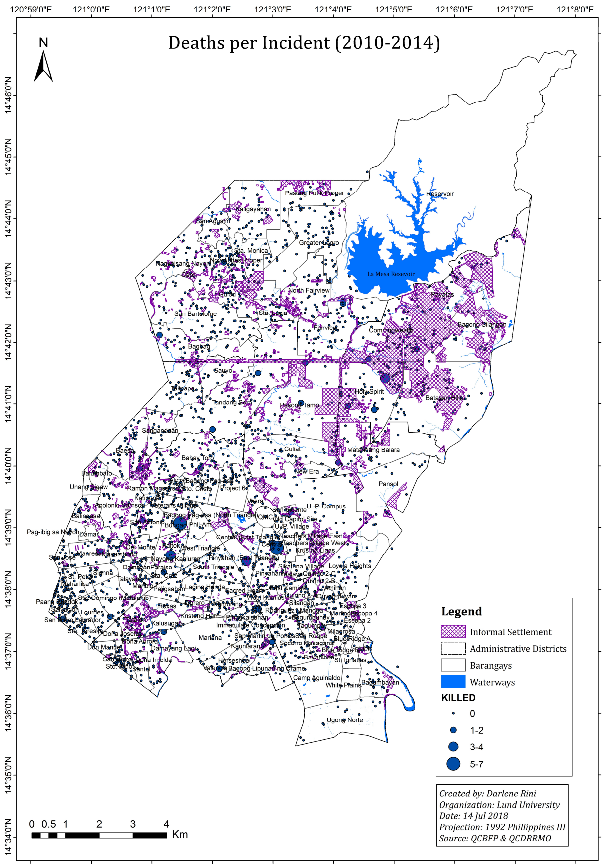



*Figure 39 - Number and percentage of fire incidents in IS areas by year*

To evaluate the impact of all urban fires and IS fires, both spatially and non-spatially, the number of deaths, injuries, houses affected and direct economic losses per incident were mapped in Figure 40 – Figure 43 with an overlay of the IS areas in purple. ***Note: In a detailed review of the BFP dataset, fire impact metrics appeared to be missing/unrecorded/grossly inconsistent between 2015-2017. So, fire impacts were assessed for 2010-2014 (5-year period).***

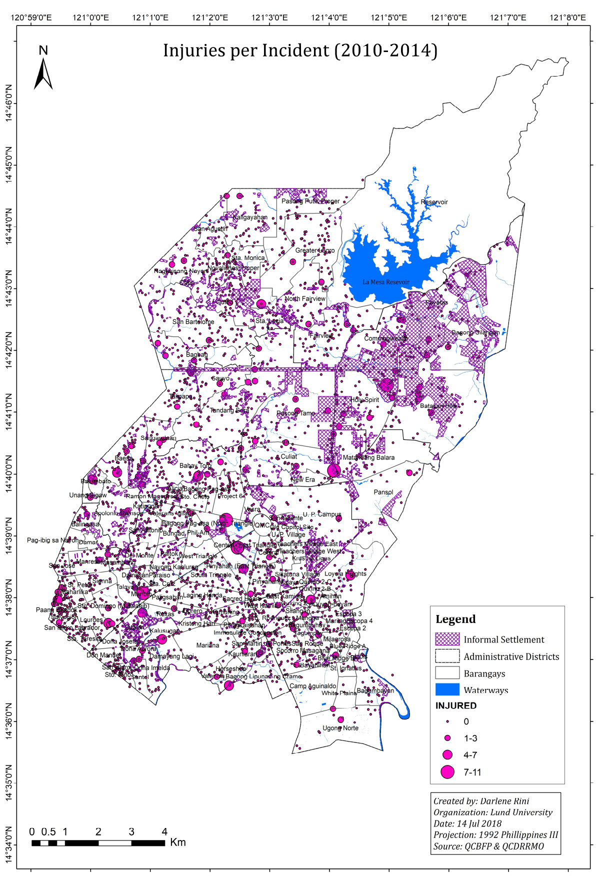
With respect to deaths per incident, the largest number is 7, while the mean deaths per incident is 0.0124 (1.24/100 fires) which is 10x higher than other major, developed cities (See ***Table 10***). We can also see that most fire deaths occur in structural fires, 58% in residential occupancies and 40% in IS areas. Comparing the death rates between residential and IS fires (0.0495 vs 0.0216), residential death rates are 2.26x higher. That is, while fires are less in formal residential areas, when there is a fire, the likelihood of death higher. This is believed by local DRM officials to be due to lower individual fire resiliency in formal residentials areas. Further, research would be required to corroborate.

For injuries, the largest incident is 11 with the mean injury per incident of 0.066 (6.6/100 fires) which is 2-7x higher than other major, developed cities (See ***Table 10***). Most injuries again, occur in structural fires, where IS impacts account for 50% of all fire events. Comparing the injury rates between residential and IS fires (0.123 vs 0.145), IS injury rates are 18% higher in ISs.




| Fire Type | Fire Incidents | | Deaths | |
|---|---|---|---|---|
| | No. | % of Total | No. | % of Total |
| All Fires | 4,280 | - | 53 | - |
| Structural - All | 1,327 | 31% | 52 | 98.1% |
| Residential | 626 | 15% | 31 | 58% |
| Informal Sett. | 971 | 23% | 21 | 40% |
| Non-Structural | 2,436 | 57% | 0 | 0.0% |
| Vehicles | 266 | 6% | 1 | 1.9% |
| Unknown | 251 | 6% | 0 | 0.0% |
| **Min** | | | **0** | |
| **Max** | | | **7** | |
| **Mean** | | | **0.0124** | |
| **Standard Deviation** | | | **0.195** | |

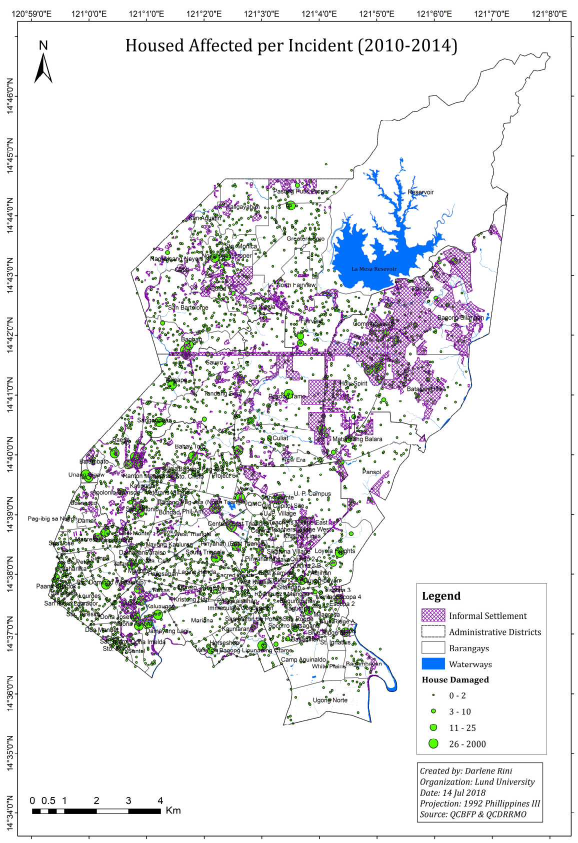
*Figure 40 – Spatial distribution of all fire deaths per incident between 2010-2014, along with basic death statistics and % occurring in IS areas.*




| Fire Type | Fire Incidents | | Injuries | |
|---|---|---|---|---|
| | No. | % of Total | No. | % of Total |
| All Fires | 4,280 | - | 282 | - |
| Structural - All | 1,327 | 31% | 229 | 81.2% |
| Residential | 626 | 15% | 77 | 27% |
| Informal Sett. | 971 | 23% | 141 | 50% |
| Non-Structural | 2,436 | 57% | 7 | 2.5% |
| Vehicles | 266 | 6% | 5 | 1.8% |
| Unknown | 251 | 6% | 41 | 14.5% |
| **Min** | | | **0** | |
| **Max** | | | **11** | |
| **Mean** | | | **0.066** | |
| **Standard Deviation** | | | **0.5187** | |

*Figure 41 – Spatial distribution of all fire injuries per incident between 2010-2014, along with basic injury statistics and % occurring IS areas.*

Turning to affected houses (Figure 42), during the 5-year period (2010-2014) nearly 7,527 houses were damaged/destroyed by fire, with the largest event affecting nearly 2000 homes. Most damaged houses occurred in IS fires (71%), which is significant since IS fires only account for 23% of the total fire count. As seen in Table 12, most high loss fire events w.r.t housing (i.e. > 6-10 damaged homes) are in IS areas. This is likely due to the combination of multiple fire safety deficiencies (e.g. densely spaced low-quality construction, presence of makeshift/combustible housing densely integrated, unknown fuel loads, limited firefighting provisions, etc.) causing high challenge fires and rapid fire spread as previously discussed.




| Fire Type | Fire Incidents | | Houses Affected | |
|---|---|---|---|---|
| | No. | % of Total | No. | % of Total |
| All Fires | 4,280 | - | 7527 | - |
| Structural - All | 1,327 | 31% | 7189 | 95.5% |
| Residential | 626 | 15% | 2529 | 34% |
| Informal Sett. | 971 | 23% | 5366 | 71% |
| Non-Structural | 2,436 | 57% | 7 | 0.1% |
| Vehicles | 266 | 6% | 16 | 0.2% |
| Unknown | 251 | 6% | 315 | 4.2% |
| **Min** | | | **0** | |
| **Max** | | | **2000** | |
| **Mean** | | | **1.759** | |
| **Standard Deviation** | | | **34.2** | |

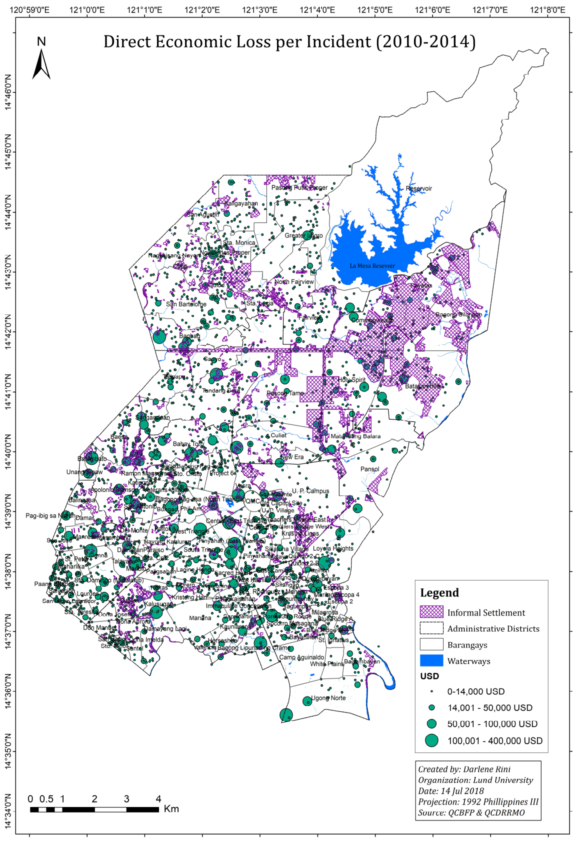
*Figure 42 – Spatial distribution of the number of affected houses per incident between 2010-2014, along with basic statistics and % occurring IS areas.*

*Table 12 - Distribution of fire incidents with number of affected houses and the portion of IS incidents*

| No. Houses Affected | All Fire Incidents | | Informal Settlment Fires | | | | Fire Incidents w/o IS | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of Incidents | % Total | No. of Incidents | % of Total | % of IS Fires | Running Total | No. of Incidents | % Total | Running Total |
| 0 | 1480 | 84% | 300 | 20% | 77% | | 1180 | 86% | |
| 1 | 198 | 11% | 49 | 25% | 13% | 90% | 149 | 11% | 97% |
| 2 | 12 | 0.7% | 3 | 25% | 0.8% | 91% | 9 | 0.7% | 97% |
| 3 - 5 | 27 | 1.5% | 13 | 48% | 3.4% | 94% | 14 | 1.0% | 98% |
| 6 - 10 | 15 | 0.9% | 9 | 60% | 2.3% | 96% | 6 | 0.4% | 99% |
| 11 - 25 | 10 | 0.6% | 4 | 40% | 1.0% | 97% | 6 | 0.4% | 99% |
| 26 - 75 | 17 | 1.0% | 6 | 35% | 1.5% | 99% | 11 | 0.8% | 100% |
| 76 - 100 | 3 | 0.2% | 3 | 100% | 0.8% | 100% | 0 | 0.0% | 100% |
| 101 - 200 | 1 | 0.1% | 1 | 100% | 0.3% | 100% | 0 | 0.0% | 100% |
| 201 - 300 | 1 | 0.1% | 0 | 0% | 0.0% | 100% | 1 | 0.1% | 100% |
| ***Total*** | ***1764*** | | ***388*** | | | | ***1376*** | | |

For financial impacts, most high loss events appear to be in the south, more centrally located portion of the city (i.e. where there is more accumulation of wealth/resources). As seen in the Figure 43, approximately $15 million USD was lost over a 5-year period, with the largest single event costing

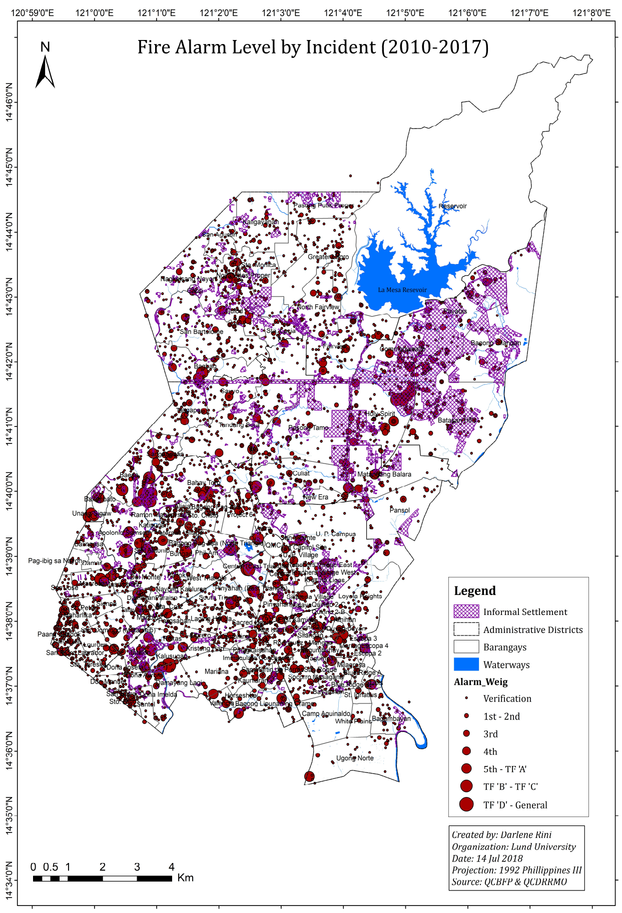
$400,000 USD. Compared to the average annual salary of 5,280 USD, the maximum loss and average loss per incident of 3,640 USD appears significant considering that most Filipinos are not insured. Regarding IS fires, which comprise 30% of the total financial losses, the average loss per event is 4,784 USD. For IS residents, this can be devastating as the average annual income is only 4,152 USD Morin, 2016)




| Fire Type | Fire Incidents | | Economic Losses | |
|---|---|---|---|---|
| | No. | % of Total | USD | % of Total |
| All Fires | 4,280 | - | $ 15,424,764 | - |
| Structural - All | 1,327 | 31% | $ 14,293,134 | 92.7% |
| Residential | 626 | 15% | $ 6,585,202 | 42.7% |
| Informal Sett. | 971 | 23% | $ 4,647,424 | 30.1% |
| Non-Structural | 2,436 | 57% | $ 108,466 | 0.7% |
| Vehicles | 266 | 6% | $ 675,898 | 4.4% |
| Unknown | 251 | 6% | $ 347,266 | 2.3% |
| **Min** | | | $ - | |
| **Max** | | | $ 400,000 | |
| **Mean** | | | $ 3,604 | |
| **Standard Deviation** | | | $ 17,230 | |

*Figure 43 – Spatial distribution of size of direct economic losses by incident between 2010-2014, along with basic financial statistics and % of loss associated with IS areas.*

Finally, in**Error! Reference source not found.***Figure 44* the fire alarm level by incident was mapped across the city and appears to show some clustering in the southern part and in District 2 areas (this will be evaluated later). As seen, most (79.6%) of the high severity fire events that are raised to Task Force (TF) Level reside in IS areas (assuming fire alarm is a proxy for fire magnitude). This indicates that these fires tend to overwhelm the first responding vehicles, requiring additional support from multiple stations/trucks and potentially from neighboring cities.




| Alarm Level | All Fire Incidents | | Informal Settlment Fires | |
|---|---|---|---|---|
| | No. of Incidents | % Total | No. of Incidents | % of Total |
| n/a | 3187 | 49.2% | 708 | 22% |
| Verification | 2551 | 39.4% | 639 | 25% |
| 1 | 256 | 4.0% | 69 | 27% |
| 2 | 203 | 3.1% | 59 | 29% |
| 3 | 147 | 2.3% | 42 | 29% |
| 4 | 63 | 1.0% | 20 | 32% |
| 5 | 35 | 0.5% | 13 | 37% |
| TF 'A' | 18 | 0.3% | 12 | 67% |
| TF 'B' | 11 | 0.2% | 11 | 100% |
| TF 'C' | 6 | 0.1% | 5 | 83% |
| TF 'D' | 1 | 0.0% | 1 | 100% |
| TF 'E' | 1 | 0.0% | 0 | 0% |
| General | 2 | 0.0% | 1 | 50% |
| ***Total*** | ***6481*** | | ***1580*** | |

*Figure 44 – Spatial distribution of fire alarm level by incident between 2010-2017, and breakdown of incidents by alarm level, and as a function of IS areas.*

### 7.2.2 Simple Spatial and Temporal Analyses

In this section, spatial clustering analysis is used to identify places of high fire concentrations and fire impacts, as well as, provide city-wide spatial fire frequency. First, using the point data of discrete fire events, continuous surfaces of fire densities have been generated by spatial point density and kernel density estimations (KDE) for comparison.

Point and kernel density surfaces are shown for all fires between 2010-2017 in Figure 45. In both maps, several high fire concentration areas (between 11 – 30 fires per year) are dispersed around the city. These areas include: Paang Bundok area, Baesa/Bahay Toro area, Novaliches/Gulod area, Holy Spirit/Commonwealth area, etc. While many of these high frequency areas appear to coincide with IS areas, e.g. 13% of all medium-high fire incidents (See Figure 46), it is not the sole predictor. For example, the Paang Bundok area contains no known ISs but has the highest fire volume. The high records in these other areas could be a result of other socio-economic deficiencies, physical vulnerabilities, and/or emergency calling behavior, as most of the incidents were either non-coded or verification status.

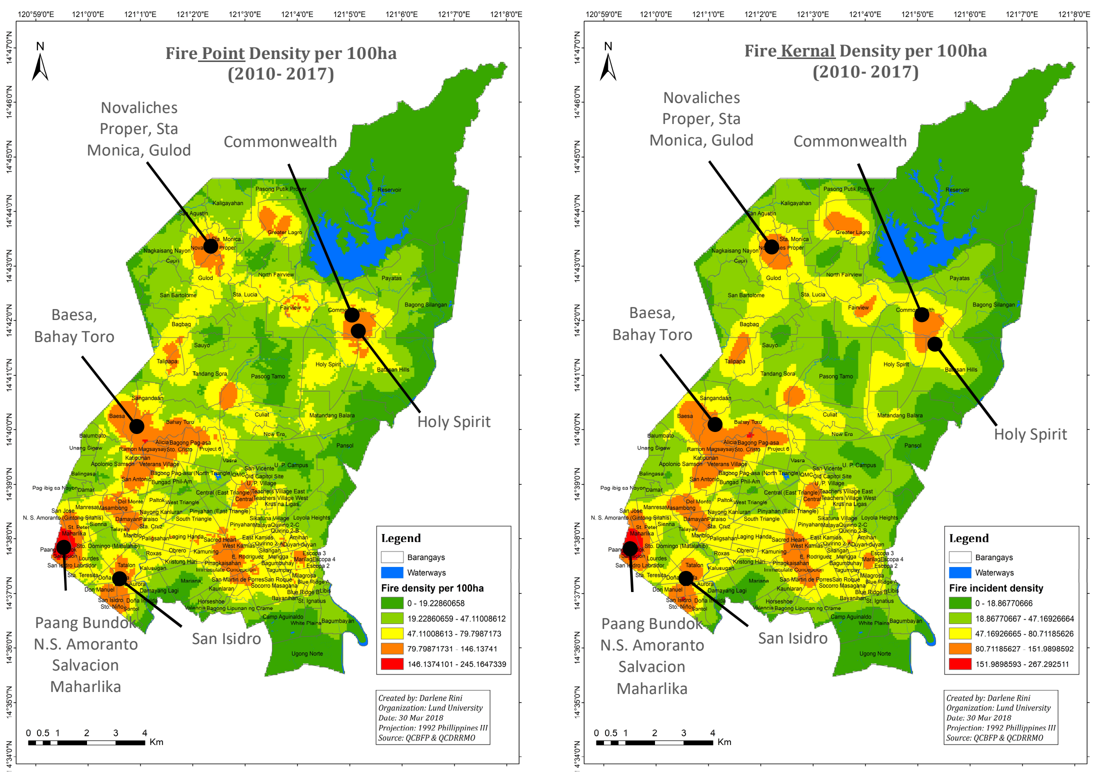
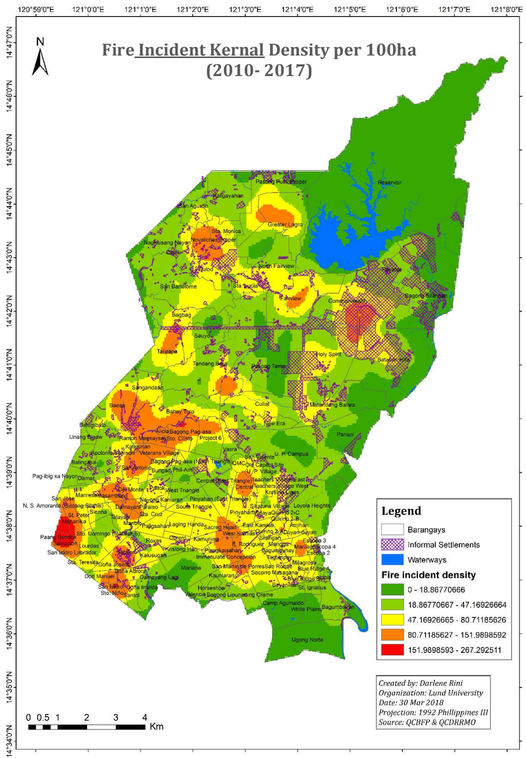



*Figure 45 - Point and kernel densities for all fire incidents (2010-2017) per 100ha area units*

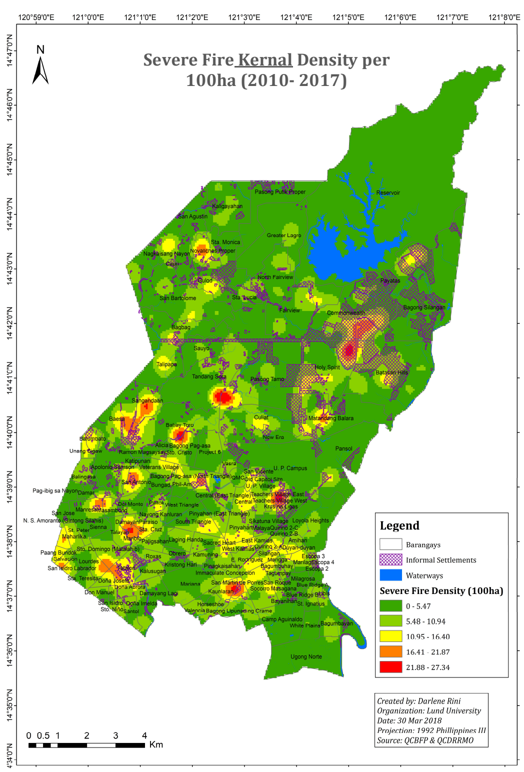
In addition to showing some IS correlation with fire occurrences, Figure 46 also provides a fire frequency map per year per 100ha areal unit with an ordinal scale based on natural breaks/clustering in the dataset.




| Ordinal Scale | Fire Incident Frequency (per 100ha) | % of Land Area | % in IS Area |
|---|---|---|---|
| Low | 2.69/year | 30.3% | 4.3% |
| Low-medium | 6.74/year | 34.3% | 12.7% |
| Medium | 11.5/year | 26.3% | 13.6% |
| Medium-High | 21.7/year | 8.7% | 13.1% |
| High | 38.1/year | 0.4% | 1.2% |

*Figure 46 - Contour map of fire incident frequency (per year/100ha) with IS area overlay*

Excluding nuisance and verification alarms, a KDE surface for only severe fires (i.e. fires with Alarm Level 1 or greater, when fire is typically observed) has been mapped in Figure 47. In this figure, there is a significantly stronger correlation of "actual fire" incidents requiring fire department activities and IS locations (~67% of severe fires med-high to high are in IS areas). A table is also provided with severe fire frequencies per year per 100ha, and a list of the top high areas.




| Ordinal Scale | Severe Fire Frequency (per year/100ha) | % of Land Area | % in IS Area |
|---|---|---|---|
| Low | 0.78/year | 65.5% | 7.8% |
| Low-medium | 1.56/year | 25.1% | 13.5% |
| Medium | 2.30/year | 7.3% | 17.0% |
| Medium-High | 3.10/year | 1.8% | 31.5% |
| High | 3.90/year | 0.3% | 36.2% |

*Figure 47 - Contour map of severe fire frequency per year/100ha with IS Area overlay. Severe is considered Alarm Level 1 and greater, which also typically corresponds to visible flames.*

*High areas: Talayan, Krus na Ligas, Holy Spirit, Commonwealth, Batasan Hils, Talaya, Baesa, Bahay Toro, Tandang Sora/Pasong Tamo, Old Balara etc.*

Looking at spatial clustering for fire impacts, KDE surfaces have been mapped for fire deaths, injuries, affected homes, and financial losses for 2010-2014 in Figure 48. Unlike the impact per incident figures in Section 7.2.1, the KDE contours illustrate the concentrations of impacts summed over time. As seen, fire impacts appear to spatially occur in the southern part of the city (i.e. where there is a higher concentration of people/buildings). In addition, for deaths, injuries and affected houses, there appears to be strong correlations to IS areas. However, for financial impacts, most high loss events do appear to coincide to the central, older part of the city where there is more accumulation of wealth/resources.

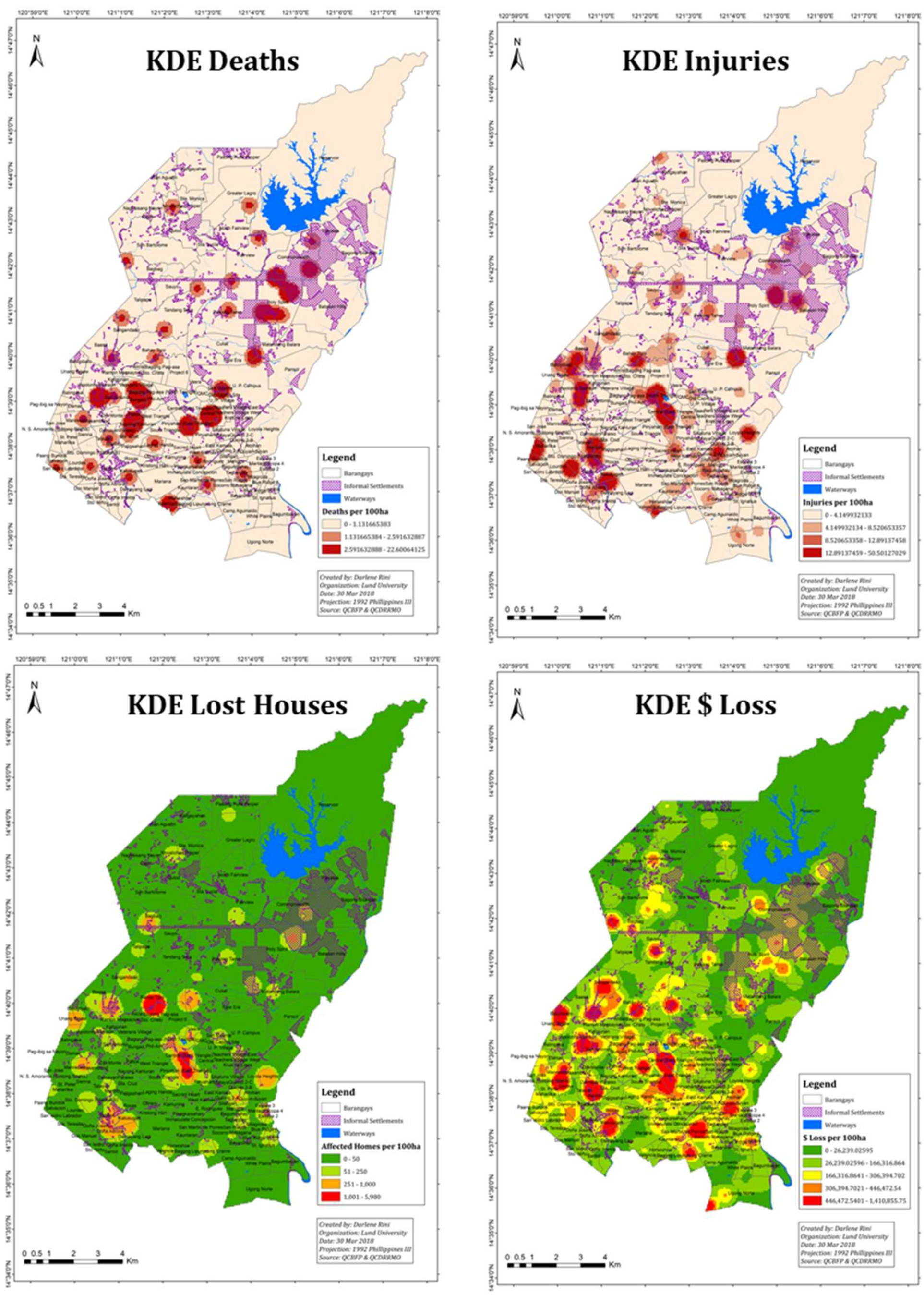



*Figure 48 – KDE analysis of fire impacts (2010-2014)*

Regarding spatiotemporal patterns, Figure 49 illustrates the time history of fire densities per 100ha from 2010-2017. High fire concentration areas are growing throughout the city, in general. Fire concentrations are also expanding from the central commercial areas towards the "suburb" areas of District 2 (i.e. Commonwealth, Holy Spirit, and Batasan Hills). Fires appear to consistently concentrate along the high hazard facilities locations of the city (Refer to land use map) and in the Paang Bundok (i.e. southwest corner of QC). It's unclear if these trends correlate with expansion/contraction of ISs.

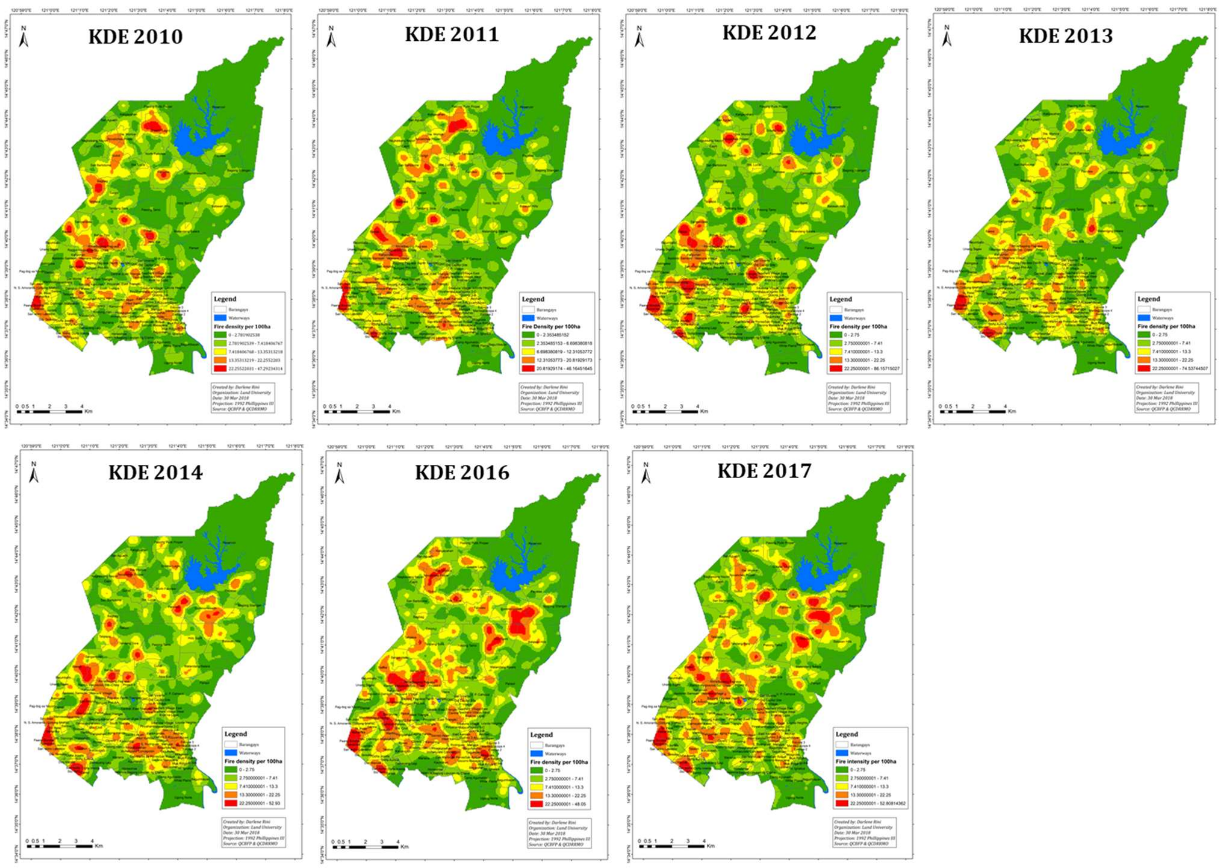
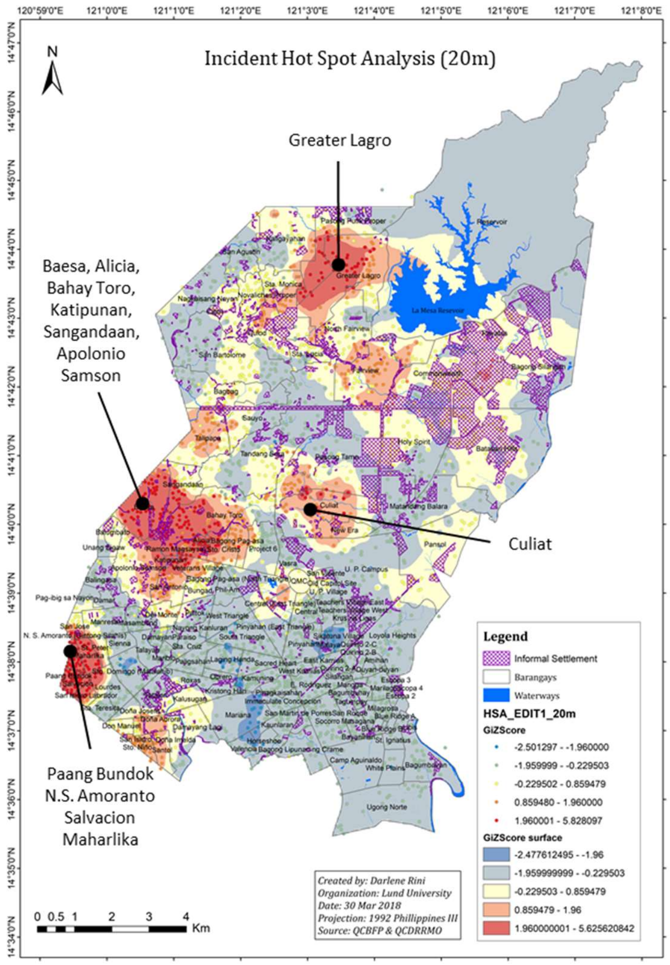



*Figure 49 – Time history of kernel densities per 100ha area units by year (excl. 2015 for lack of data)*

### 7.2.3 Geospatial Statistical Analysis

While spatial clustering methods, e.g. point density and KDE, provide valuable insight into locations of high fire concentrations, as well as, an indication of city-wide fire frequencies, they are subject to unit of area/scale (i.e. bandwidth subjectivity) and provide no statistical information. Thus, hot spot analyses were performed to assess where there are statistically significant hot/cold spots for fire incidents, severe fire incidents and fire impacts.

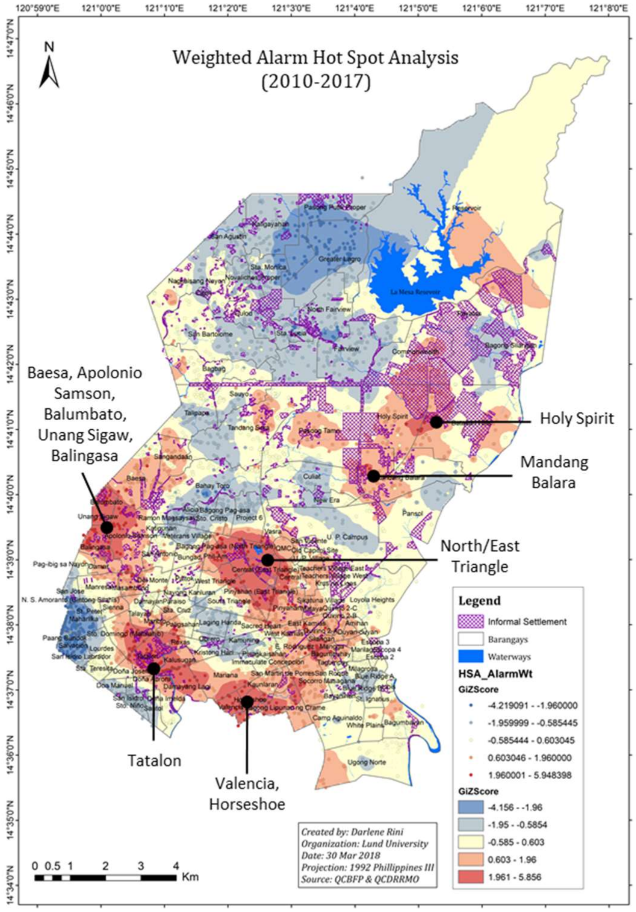
Figure 50 presents the results of the hot spot analysis for all fire incidents between 2010-2017. Areas with significantly higher fires (p-value < 0.05, z-score > 1.96) and conversely, lower fire rates (p-value < 0.05, z-score < 1.96) are both observed. The "hot" areas are shown in red and the "cold" areas are shown in dark blue. Like the KDE analysis, fire "hot" spots appear in the Paang Bundok area (SW corner), the Baesa/Bahay Toro area near a large IS area, Culiat area and Greater Largo area near a CBD. Areas with lighter color (yellow, light blues) have no statistically significant clustering of fires. Note: the Moran's I stats for the analysis are: bandwidth=1.06km, I = 0.013, Z=3.66, p-value<0.0002)




| Confidence Levels | % of Incidents | % of Incident Confidence Level in IS Area |
|---|---|---|
| 99% | 3.7% | 16.9% |
| 95% | 1.4% | 12.5% |
| -95% | 0.9% | 8.5% |
| -99% | 0% | 0% |

*Figure 50 – Hot spot analysis of fire incidents, assuming point integrate = 20m (2010-2017). Overlay of IS areas is provided with tabular breakdown of statistically significant hot spots and cold spots as % of all incidents and % of incidents in IS Areas.*

Figure 51 presents the results of the hot spot analysis based on fire severity (i.e. Alarm Level 1 and higher). Severe fire hot spots are seen to generally cluster in the southern part of the city. The main severe hot spots are in the Baesa area, Tatalon, parts of Mandang Balara, Holy Spirit and East/West Triangle areas – all locations with large IS areas – Valencia/Horseshoe area and Silangan area. Severe fire hot spots in IS areas comprise a large percentage (37.5%) of statistically significant severe fire hot spots with a 99% confidence level ($p<0.01$, $z > 2.58$). Interestingly, hot spots are no longer observed in Paang Bundok and Greater Lagro areas, indicating that most of those calls in Figure 50 were of low fire importance (possibly false alarms).




| Confidence Levels | % of Incidents | % of Incidents in IS Area |
|---|---|---|
| 99% | 4.0% | 37.5% |
| 95% | 4.0% | 17.3% |
| -95% | 8.6% | 5.7% |
| -99% | 4.0% | 2.2% |

*Figure 51 – Hot spot analysis of weighted fire incidents based on alarm level (2010-2017). Overlay of IS areas is provided with tabular breakdown of statistically significant hot spots and cold spots as % of all incidents and % of incidents in IS Areas. A high percentage of statistically significant severe fires are shown to cluster in IS areas (37.5%)*

Results of a temporal analysis of severe fire hot spots are shown Figure 52. This map compares the results of hot spots during 2010-2017 period and during 2013-2017 period. In both cases, hot spots are in similar places except for the Central East Triangle/ North Triangle area. After 2012, the hot spots in this area are no longer present. This may be due to large clearings of IS areas (e.g. San Roque) which occurred around this time-period in preparation for redevelopment of Vertis North into a major mixed-used commercial area (M. Marasigan, personal communication, December 2017). ***This also may suggest that IS areas (or removal of) can have statistically significant impact on fire risk – in this case the reduction in severe fire incidents/calls***. This assessment is corroborated by a temporal hot spot analysis of IS fires only, shown in Figure 53, but would require further investigation to verify that other factors are not influencing these observations.

Regarding fire impacts (deaths, injuries, etc), results of hot spot analysis for injuries are shown in Figure 54. For deaths, affected houses, and economic losses, no spatial autocorrelation was observed based on geospatial parameters and thus no statistically significant hot spots. For fire injuries, however, the observed hot spots appear to correlate with the same locations of severe fire hot spots, except for Loyola Heights and Ugong Norte area. ***Note: A major fire incident in a multi-unit high rise occurred in Loyola Heights in 2014, which could explain the hot spot in that barangay. The Ugong Norte hot spot appears to be an edge of analytical window error, and not injury hot spots.***

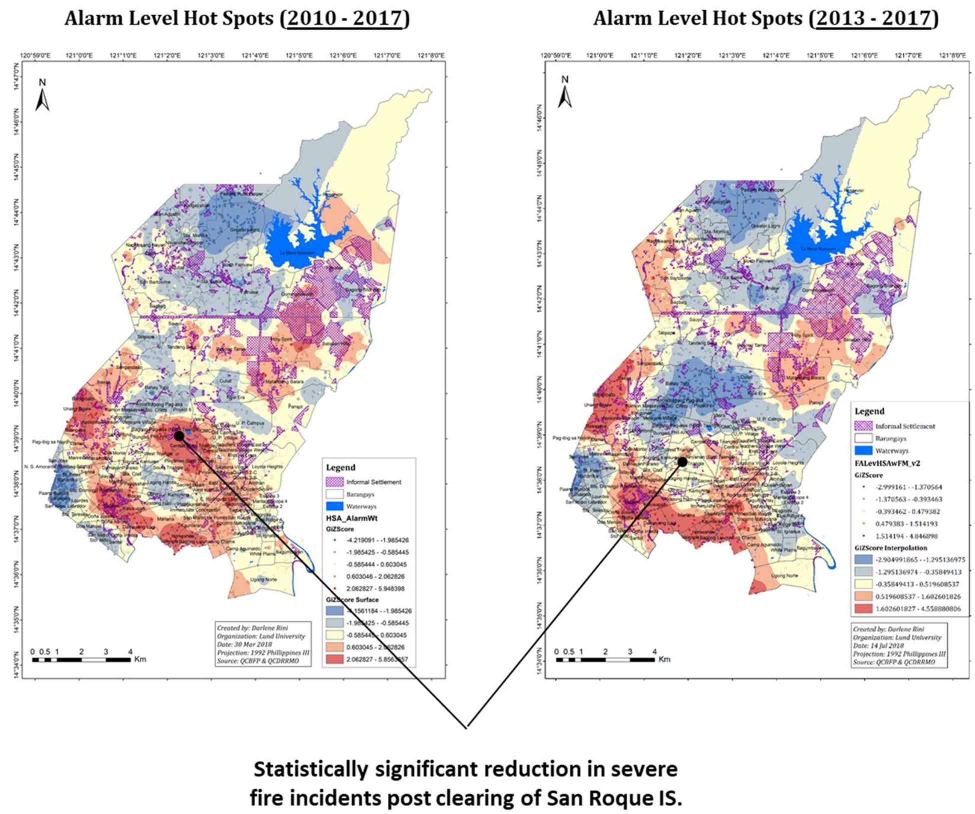



*Figure 52 – Temporal assessment of hot spot analyses using a weighted fire severity scale for all fires for two time periods (2010-2017 vs 2013-2017).*

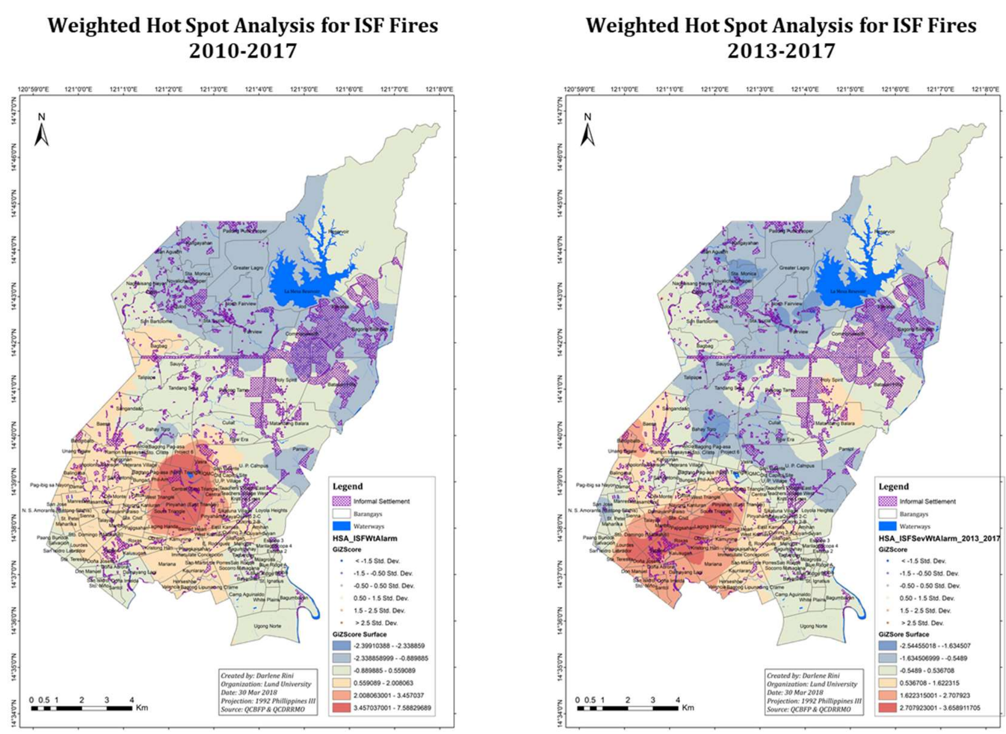



*Figure 53 – Temporal assessment of hot spot analyses using a weighted fire severity scale for IS fires only for two time periods (2010-2017 vs 2013-2017).*

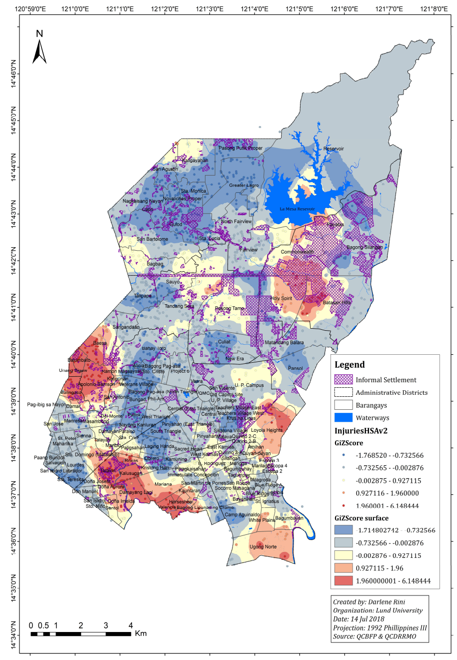
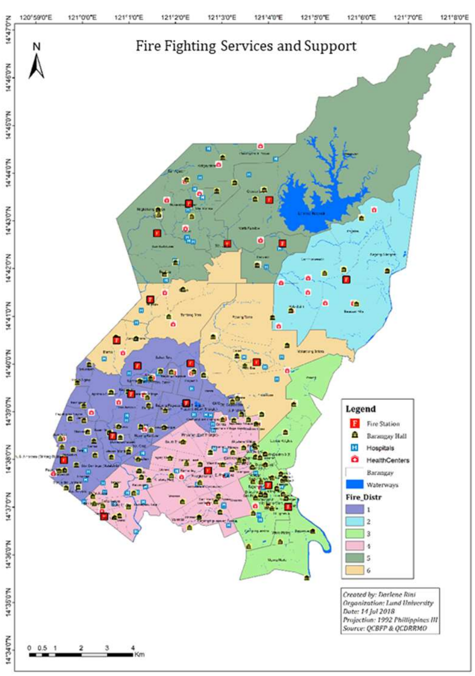



*Figure 54 – Hot spot analysis of fire-related injuries between 2010-2017*

### 7.2.4 Fire Service Coverage Area Analysis

This section presents the evaluation of the fire service capacities for QC based on four metrics: personnel, fire trucks, station response times and fire hydrant coverage/spacing. These parameters were compared to NFPA and other international standards. Figure 55 indicates the locations of all BFP main fire stations (6 total) and substations (15), along with the corresponding personnel and fire truck resources. As shown, the staff and truck resources are significantly below international standards. The highest deficiencies, however, are primarily in Station 2, 5, and 6, which also have the largest areas of IS areas and are further from the main city center.

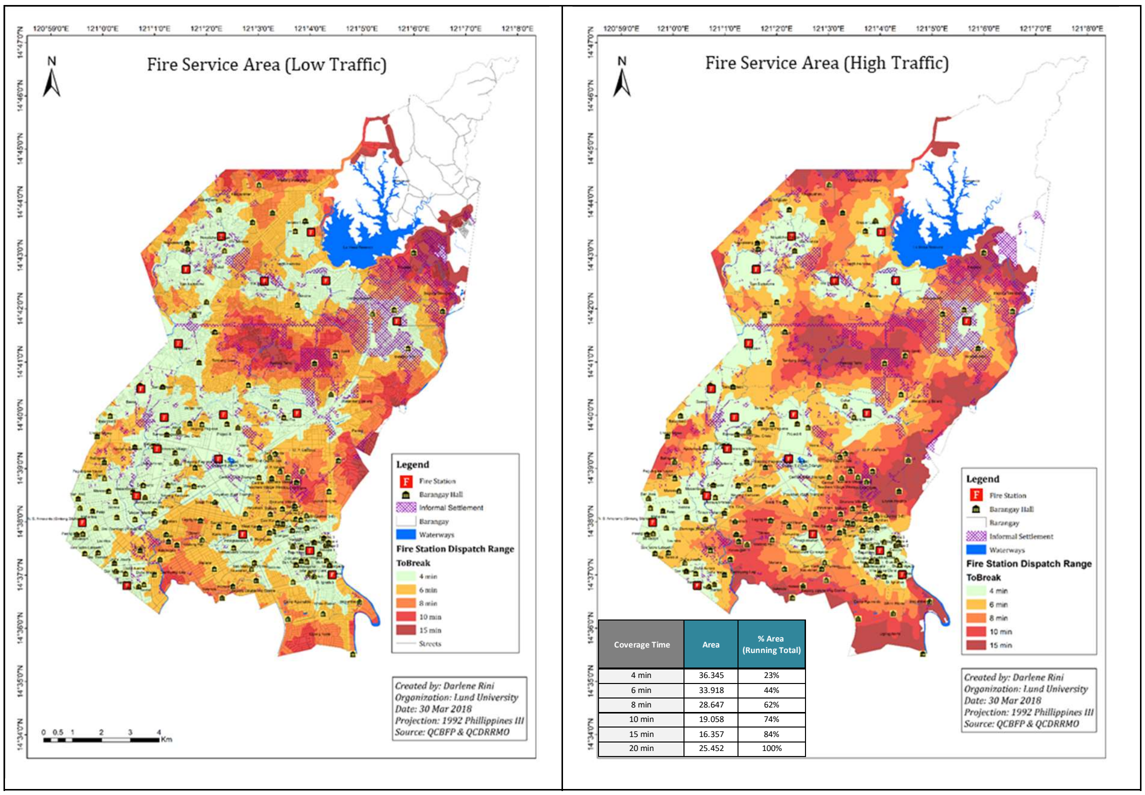



| Station | No. of Barangays | Population | Criteria: Personnel (1:2,000) Required | Actual | Status | Trucks (1:28,000) Required | Actual | Status |
|---|---|---|---|---|---|---|---|---|
| 1 | 46 | 414,039 | 207 | 114 | (93.02) | 15 | 6 | (8.79) |
| 2 | 5 | 635,967 | 318 | 39 | (278.98) | 23 | 3 | (19.71) |
| 3 | 37 | 307,638 | 154 | 65 | (88.82) | 11 | 3 | (7.99) |
| 4 | 38 | 428,555 | 214 | 77 | (137.28) | 15 | 7 | (8.31) |
| 5 | 11 | 488,172 | 244 | 93 | (151.09) | 17 | 2 | (15.43) |
| 6 | 11 | 487,349 | 244 | 46 | (197.67) | 17 | 3 | (14.41) |
| | | | | 24 | | | | |
| Total = | 148 | 2,936,116 | 1,469 | 599 | (870.00) | 105 | 26 | (79.00) |

*Figure 55 – Evaluation of Firefighting services against NFPA performance criteria*

Regarding fire stations, the most critical aspect in determining station capacity is response time – the time for firefighters to reach the fire event and begin suppression, search and rescue and medical services. This is because time has a direct relationship with fire loss (i.e. the longer the response time the more critical and extensive the fire impacts). This can be better understood by the relationship time has to fire growth. Refer to Annex B for further explanation. The results of the response times calculations at 4, 6, 8, 10 and 15min during low traffic (Sunday at 2:00) and high traffic conditions (e.g. Friday at 17:00) are presented in Figure 56. The areas highlighted in light green are the areas of the city that are within 4 min travel time of a station. After dispatch and turnout time, a 4-minute travel time to arrive on site is considered ideal per NFPA 1710. In some jurisdictions (including QC), the target time is 5min due operational requirements and practical limitations. Thus, areas in light orange is the additional area that is covered by a 6 min target.

As seen, there are many parts of QC that are outside the ideal response time for both 4min and 6min. During high traffic conditions, more than 50% of the city is outside the ideal 4min (for IS areas it is 55%). While the coverage of the city is improved during the low traffic analysis, the city is notorious for extreme congestion and without the presence of emergency lanes, response times will more likely reflect those of high traffic.




| Coverage Time | Area | % Area (Running Total) |
|---|---|---|
| 4 min | 36.345 | 23% |
| 6 min | 33.918 | 44% |
| 8 min | 28.647 | 62% |
| 10 min | 19.058 | 74% |
| 15 min | 16.357 | 84% |
| 20 min | 25.452 | 100% |

*Figure 56 - Fire station coverage area analysis using Response Times during Low and High Traffic*

Since response time analysis in ArcGIS may not capture all "in life" conditions, a hot spot analysis of historical response times between 2010-2017 has been undertaken and presented in Annex D1. While the GIS predictive response time map differs from the historical times, there are consistently high response time areas in both (i.e. Pasong Tamo, Tandang Sora, Pasong Putik Proper).

Another major part of the firefighting response time cycle is the timeliness of starting suppression. This was evaluated using a geospatial analysis of the hydrant waterflow coverage (per NFPA 1) and hydrant spacing along the street. The results of both analyses are presented in Figure 57. As seen in the figure and in Table 13, all hydrant coverage areas (50m, 100m, 150m radii), which correlate to different waterflow criteria (i.e. 1500gpm, 1000gpm) for typical occupancies, in majority of the city is underserved. This means that in the event of the fire, it is likely that water flow will be diminished, making fire suppression/control inefficient and life threating. While fire trucks can be equipped with water pumps, most in QC do not have such equipment (Chief Le Roy, personal communication, January 2018).

As also seen in Figure 57 and Table 14, for both hydrant street spacings (150m, 300m) which correlates to the distance fire vehicles must travel before reaching the closest hydrant, the majority of the city is underserved at the typical 150m spacing for most types of occupancies per NFPA standards (i.e. 46% of the city streets do not have hydrants spaced every 150m). At 300m spacing, only 23% of the city streets would be deficient. The impact of deficient hydrant spacing (i.e. more than 75m max distance from a hydrant to a fire truck) is that more than two supply hoses would be required to connect a hydrant to the closest pumper truck (as a standard supply hose line is 30.5m). The additional time to connect more hose lines means additional time wasted setting up operations instead of suppressing/containing the fire and limiting fire impacts to life and property.

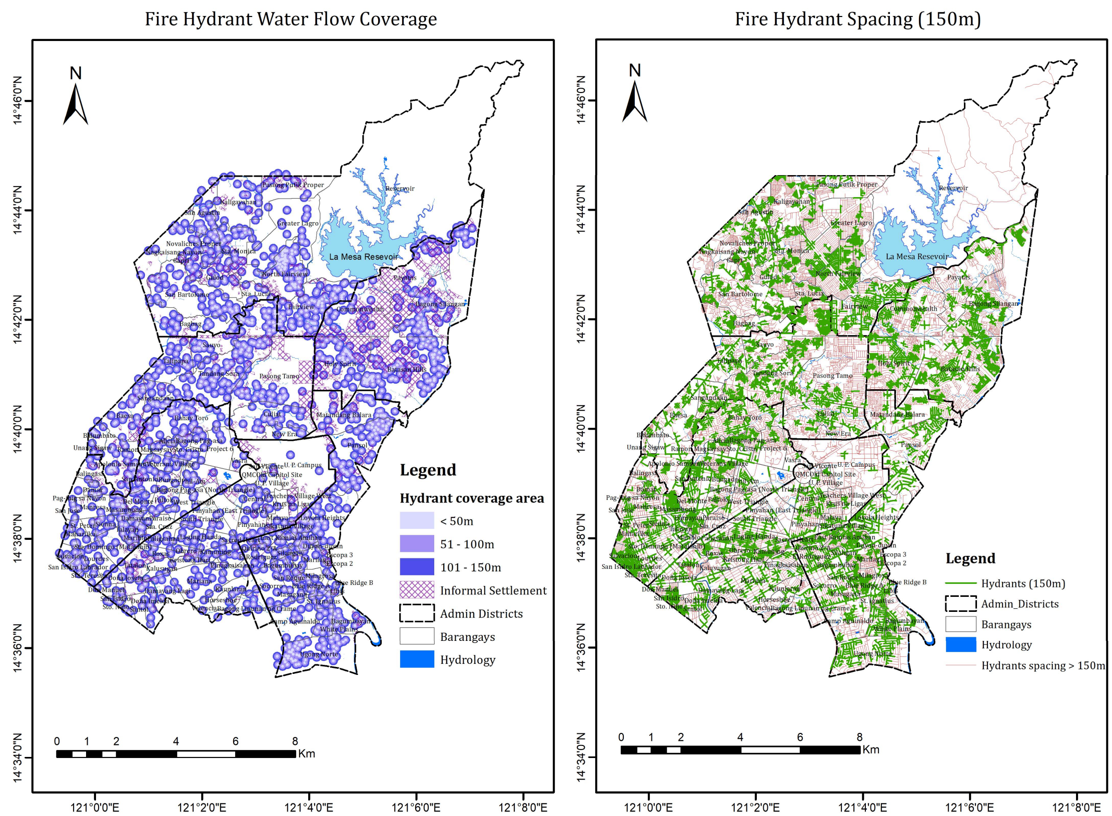



*Figure 57 – (Left) Fire hydrant water flow coverage (Buffers = 50m, 100m, 150m) and (Right) Fire hydrant spacing using network analysis (150m)*

*Table 13 - Summary of hydrant waterflow coverage area for 50m, 100m and 150m*

| Total Land | Land Area Within Distance of Hydrant | | | % Deficient | | |
|---|---|---|---|---|---|---|
| Area | 50m | 100m | 150m | 50m | 100m | 150m |
| [km2] | [km2] | [km2] | [km2] | [%] | | |
| 161.6 | 11.9 | 28.4 | 29.7 | 0.93 | 0.82 | 0.82 |
| | | | | | | |

*Table 14 - Summary of hydrant spacing coverage for 150m and 300m spacing*

| Total Street Length | Total Street Length with Hydrant Spacing | | | |
|---|---|---|---|---|
| | Spacing = 150m | % Deficient | Spacing = 300m | % Deficient |
| [m] | [m] | [%] | [m] | [%] |
| 2,274,656 | 1,229,183 | 46% | 1,754,688 | 0.23 |
| | | | | |

### 7.2.5 Correlation of Socio-Economic Variables and Fire Incidents

Due to significant issues with inconsistent areal units (i.e. barangays), the exploratory regression analysis intended to assess correlations between socio-economic variables to fire incidents was not completed. Refer to Annex D.4 for detailed discussion.

## 7.3 URBAN FIRE RISK INDEX

This section presents the results of a fire risk assessment of QC that is based on a composite integration of historical fire impacts, social vulnerabilities and coping characteristics in the city. The assessment is based on a modified URDI approach (Cardona et al., 2005) as a tool for evaluating urban fire risk using historical fire data in Section 7.2.1 and introducing firefighting vulnerabilities based on analysis in Section 7.2.4. The intent is to provide an urban fire risk index to enhance the existing URDI for seismic and flood risks in the QC Risk Atlas (QCDRRMO, 2013/1). The aim is to mainstream holistic urban fire risk into the overall city disaster risk management system.

### 7.3.1 Fire Frequency

Before this study, there was no comprehensive city-wide fire risk assessment for management purposes. Although not part of the URDI methodology, preliminary city-wide fire frequency maps have been created by aggregating the point fire incident records/data presented in the previous sections to the barangay level. See Figure 58

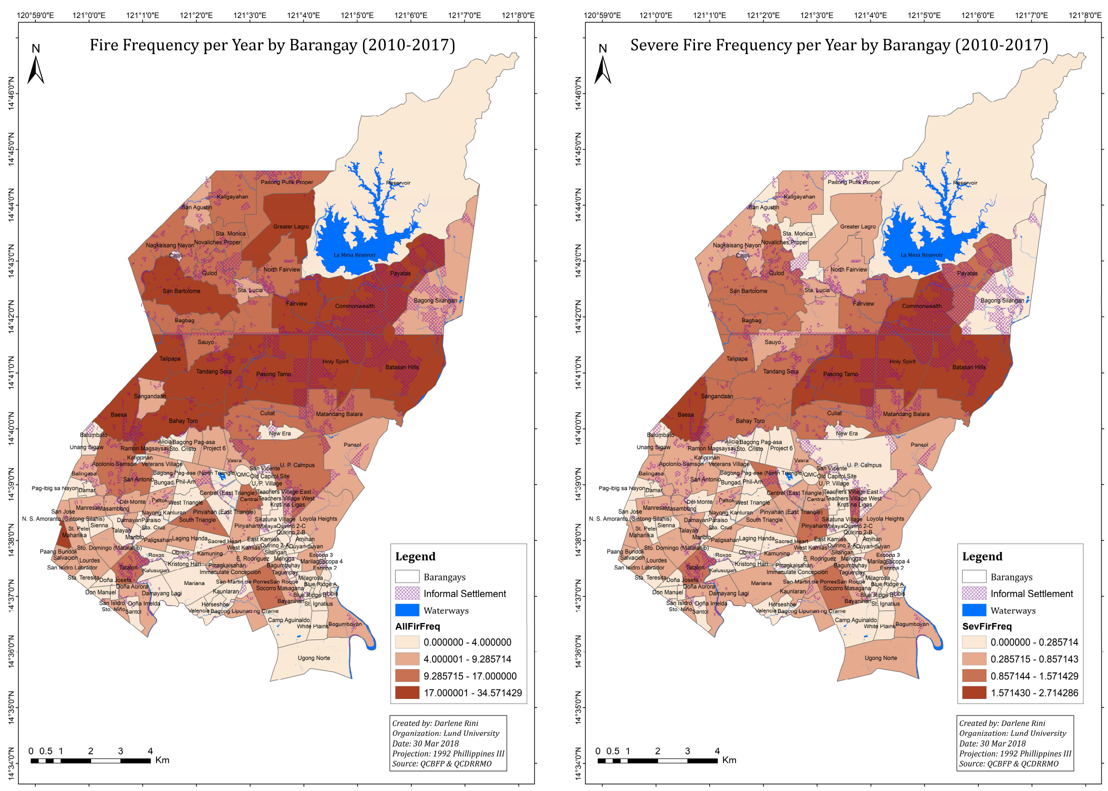



*Figure 58 - (Left) Annual fire frequency by barangay (Right) Annual severe fire frequency by barangay*

### 7.3.2 Fire Risk – Physical Impacts

As indicated in the methodology in Section 4, two main categories are used to define physical fire impacts: population loss index (i.e. deaths and injuries) and building loss index (i.e. economic losses and affected buildings). The raw data for the indicators is shown in Figure 59 and Figure 60.

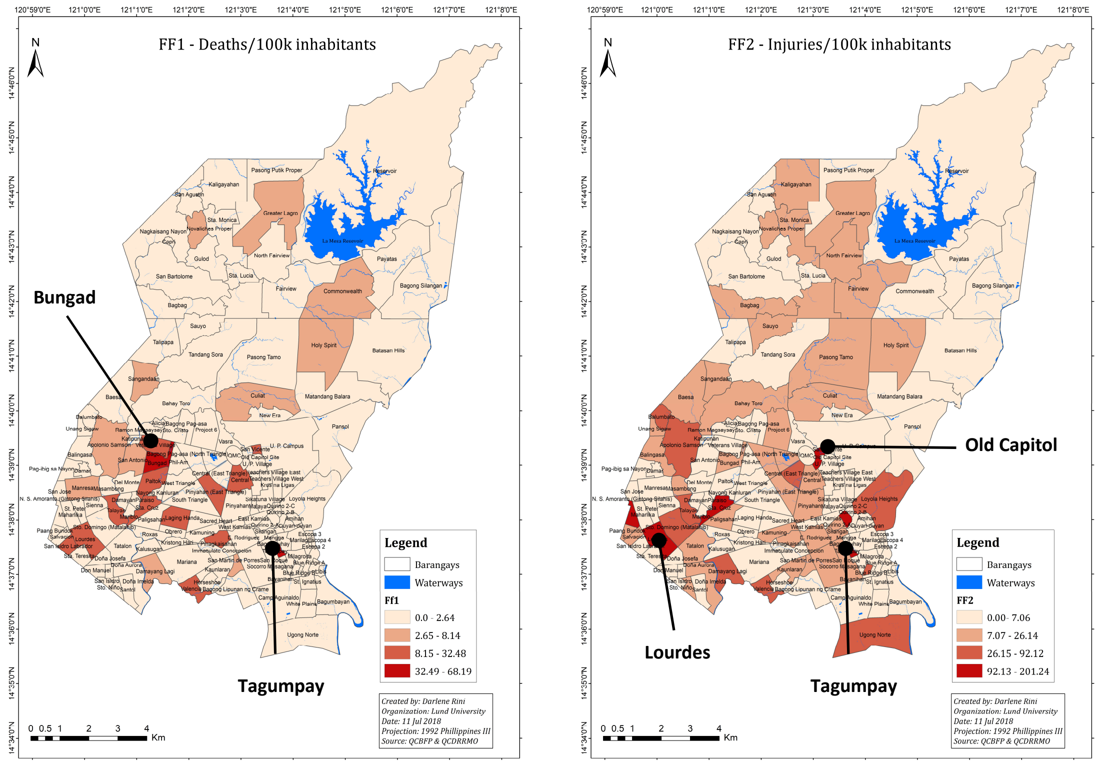



*Figure 59 – Fire deaths and injuries per 100k inhabitants by barangay between 2010-2017*

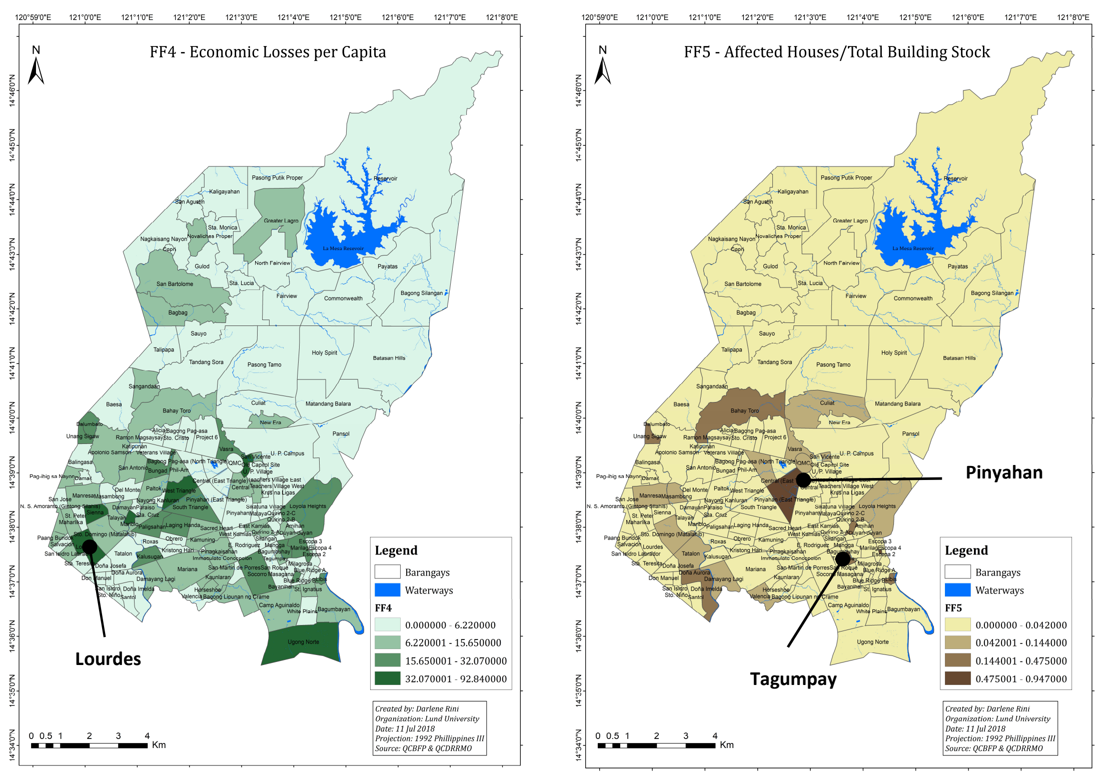
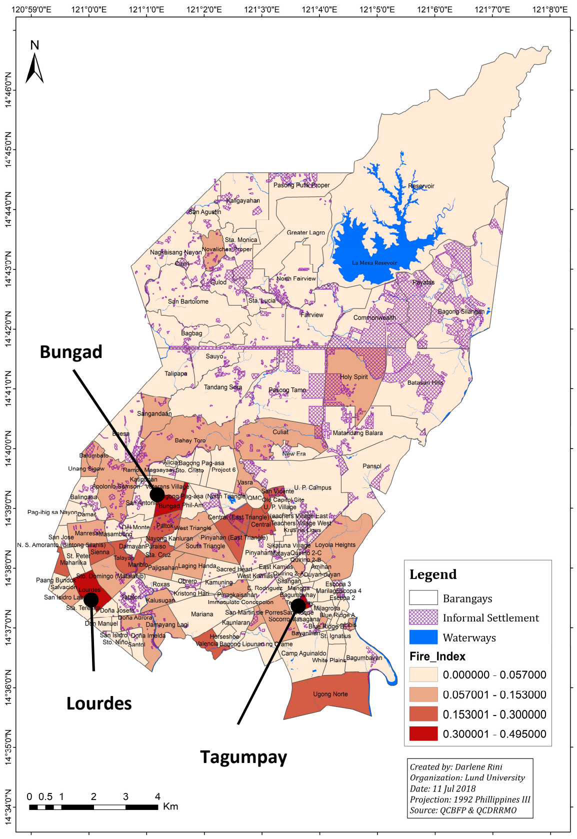



*Figure 60 – Economic losses and affected buildings by barangay between 2010-2017.*

The aggregated fire physical risk as a weighted sum of population loss and building loss is given in *Figure 61*, along with the top 12 barangays for each of the two sectors. The weights for each sub-indicator and sub-indices are in Annex D.



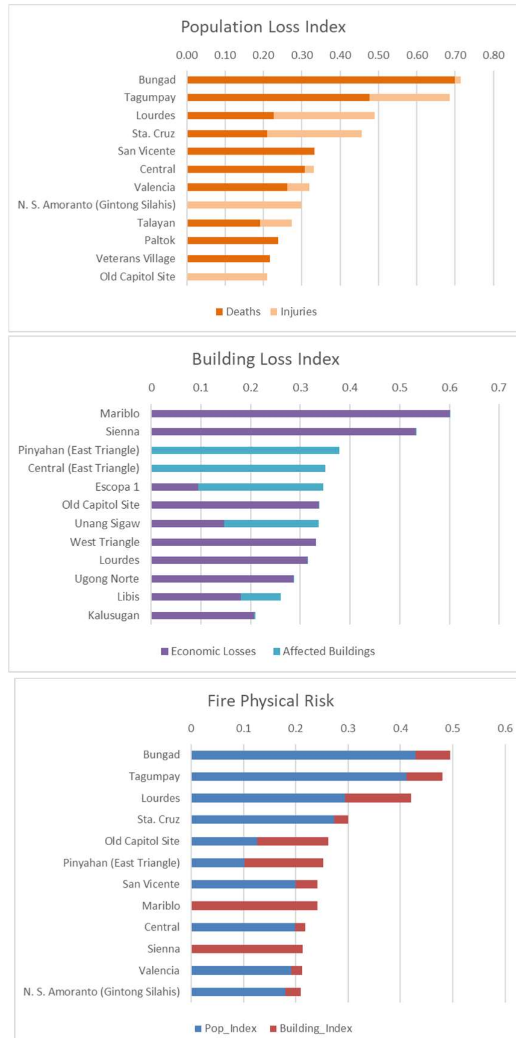




*Figure 61 - (Left) Fire physical risk based on weighted aggregation of population & building losses (Right) Top 12 Barangays for population index, building index, and overall fire physical risk*

As seen, the physical fire impact is significantly larger for Bungad, Tagumpay and Lourdes compared the other barangays. This is due to the consistently high number of deaths, injuries and financial losses per capita each year (See *Figure 59* and *Figure 60* ). Tagumpay has also had some high building loss events from some IS fires.  It is interesting to note that many of the large IS and high fire loss areas (in absolute numbers) do not show in the top 12. This results from normalizing the impacts against population and from the weighted aggregated sum of all the impacts producing different combinations of overall physical impact, as well as, related to areal unit issues described earlier and further in the discussion.

### 7.3.3 Socio-economic Impact Factors

The socio-economic impact factor is based on two main-categories: Social Vulnerability index and Lack of Coping Capacities. The social vulnerability index and all its sub-indicators have been directly adopted from the previous HVRA study (QCDRRMO, 2013/1) for seismic and flood risk and therefore not presented herein. See maps and details in Annex D.

The Lack of Coping Capacities index, however, has been modified as a function of three sub-categories: Lack of Mitigation & Prevention, Lack of Hospital Capacity, and Lack of Firefighting Services. The first two categories have been directly adopted from the HVRA study. See Annex D for maps of those indicators. The Lack of Firefighting Services is comprised of four indicators: response time, hydrant coverage, staff ratio and truck capacity (as discussed in Section 4). The maps of the raw data by barangay for these four indicators are seen in *Figure 62*.

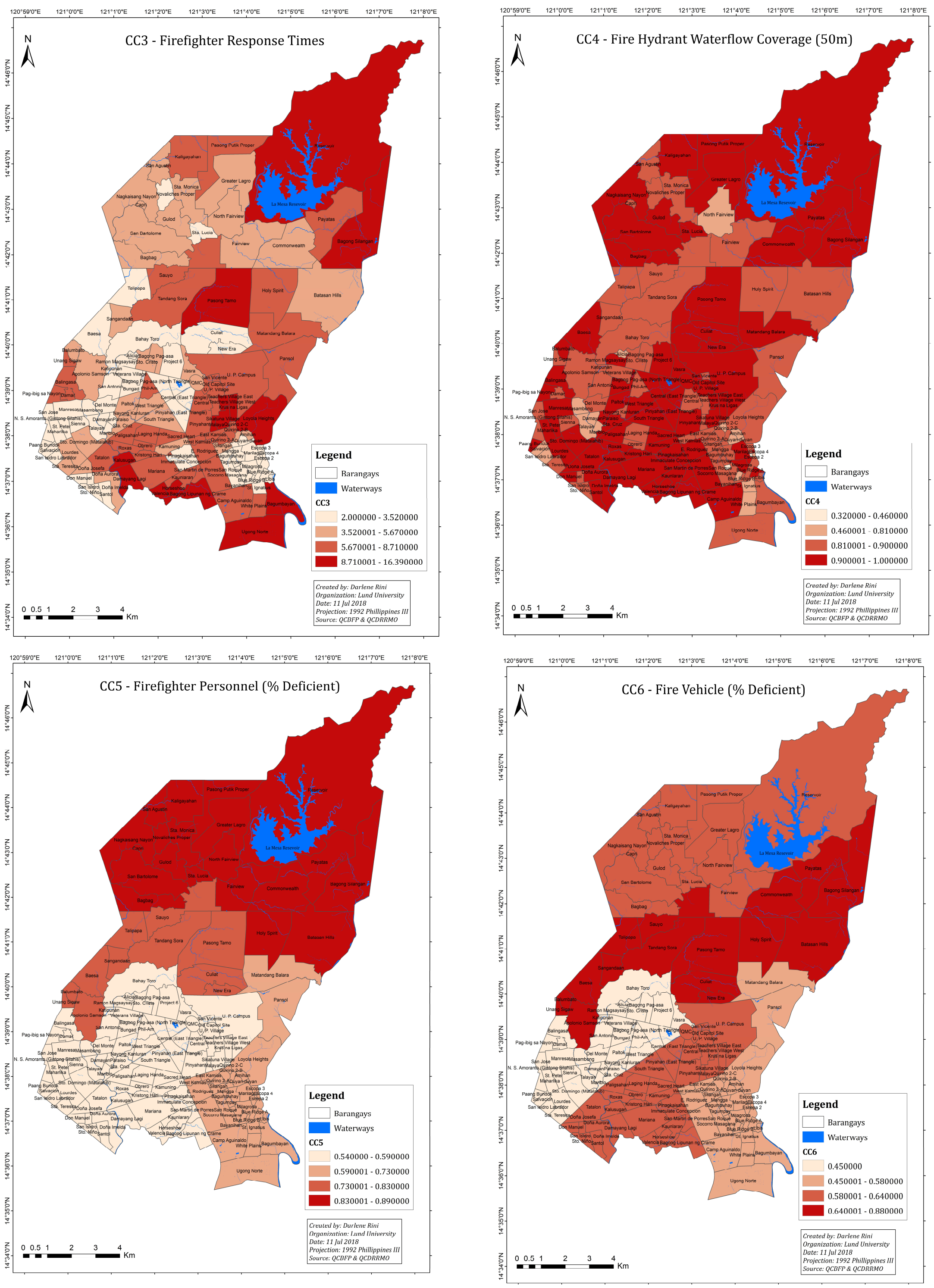
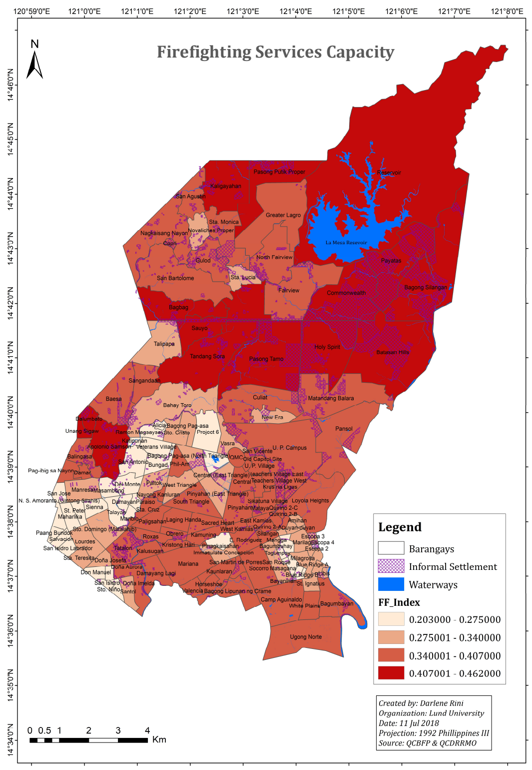



*Figure 62 – Firefighting services indicators per barangay between 2010-2017*

The indicators were normalized, and the weighted, aggregated firefighting services capacity index is given in *Figure 63*, along with the top 12 firefighting deficient barangays. The weights for each sub-indicator are in Annex D.



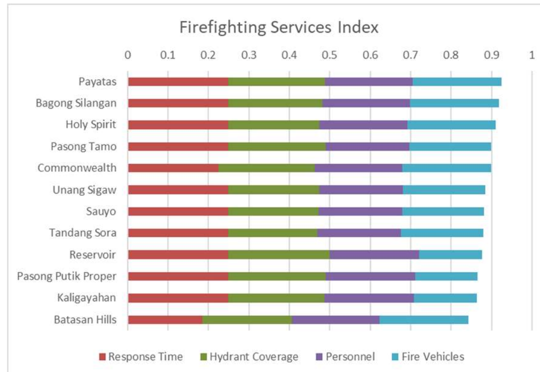
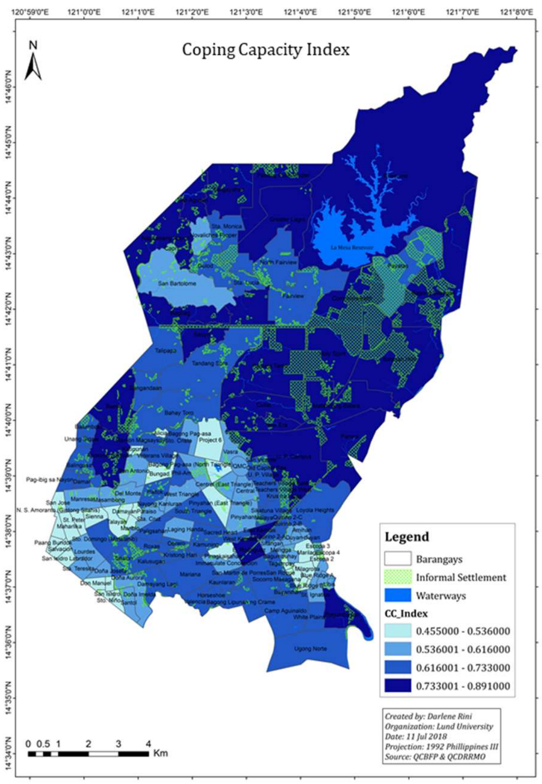




*Figure 63 - (Left) Firefighting services index based on weighted aggregation of response time, hydrant coverage, firefighter personnel, and fire truck capacity (Right) Top 12 Barangays for overall firefighting capacity index.*

In terms of the four proxies for firefighting capacities, Payatas has the lowest capacity. That said, much of the city is deficient in one or multiple firefighting services, which puts the whole city at risk. As the weighting factor for each indicator was set at 0.25, the proportion of each component for the top 12 barangays is relatively equal. Note: QC has additional firefighting resources in the form of volunteer firefighters with staff and equipment throughout. Some barangays, as well, have additional dedicated services. However, official firefighting is conducted by BFP, who are trained to international standards and assume command for all fire events. Therefore, all major fires are subject to BFP capacities, regardless of presence of volunteers of unknown capacity and quality.

Given the firefighting service index, the overall coping capacity index has been calculated based on weighted aggregation of hospital capacity index and the mitigation/prevention indicator. The rankings for the lack of coping capacity index are plotted in *Figure 64*. While Pasong Tamo has the lowest coping capacity for all the barangays, the top 12 all appear to have very similar indices. The rankings of social vulnerability factors are plotted in *Figure 65* and are based on a vulnerable groups index, population density, education, sub-standard housing, and crime rate. The three Escopa and Botocan have the highest social vulnerabilities, with highly vulnerable groups and population density contributing the most to social fragility.



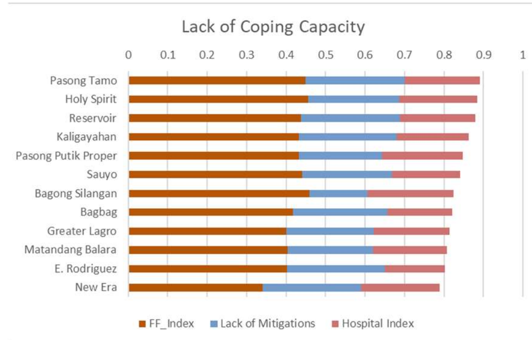
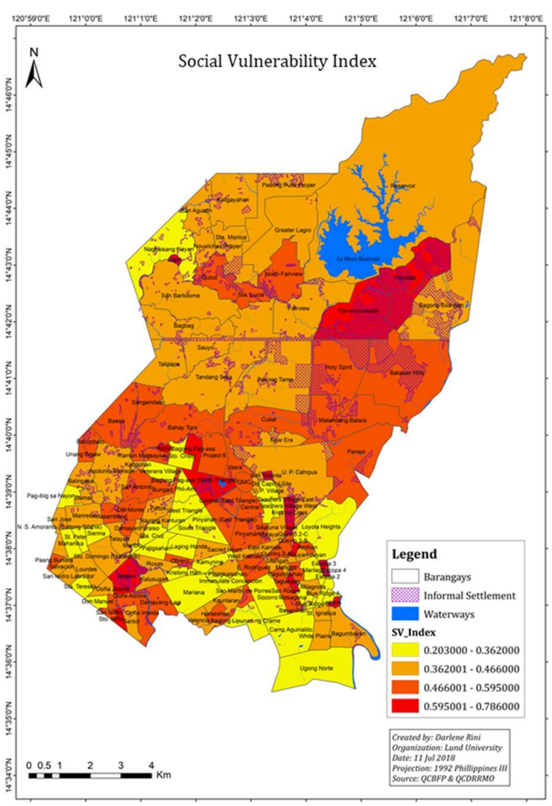




*Figure 64 - (Left) Lack of coping capacity index based on weighted aggregation of firefighting capacity, lack of mitigations, hospital capacity (Right) Top 12 Barangays for overall lack of coping capacity index.*



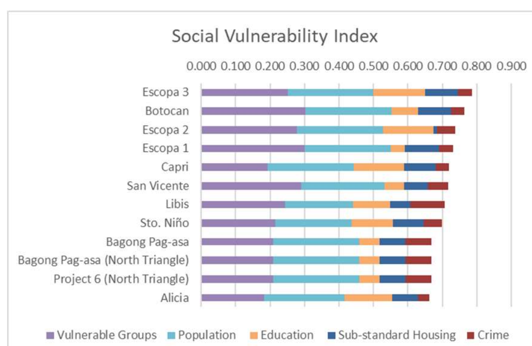
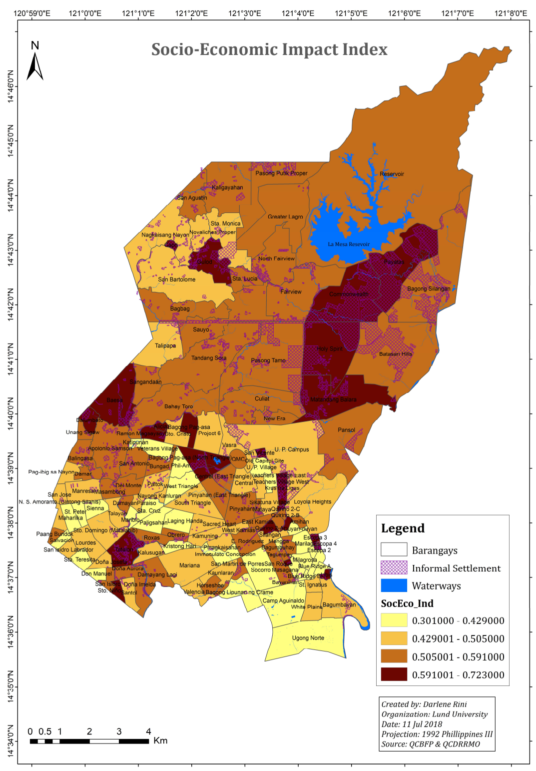




*Figure 65 - (Left) Social Vulnerability index based on weighted aggregation of vulnerable groups, population, education, sub-standard housing and crime (Right) Top 12 Barangays for social vulnerability.*

The aggregated socio-economic impact factor, as a weighted sum of social vulnerability and lack of coping capacity is given in *Figure 66* along with the top 12 barangays for each of the two sectors. The weights for each sub-index are in Annex D. In this figure, Escopa 3 and Botocan have the highest socio-economic impact factors. These two barangays also had the highest social vulnerabilities index. In fact, several of the top 12 in socio-economic factors are in the top for social vulnerability. It can also be seen that others, are not necessarily in the top for either index, but due to a combination of different measures their overall ranking is high (e.g. Tatalon, Commonwealth)



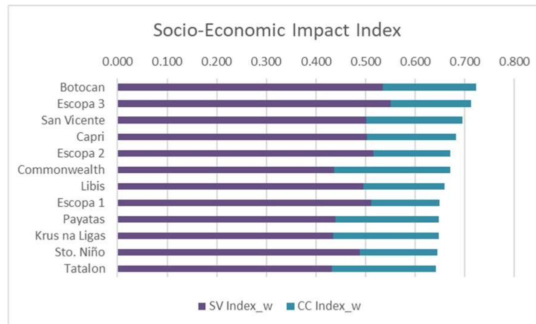
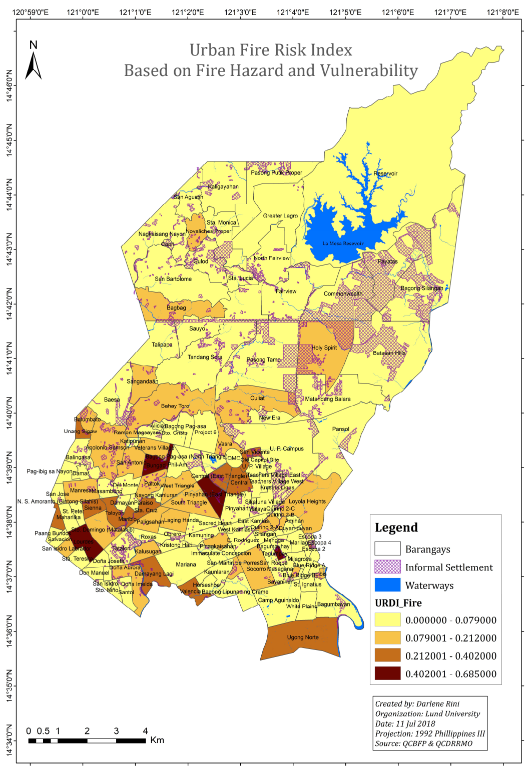




*Figure 66 - (Left) Socio-economic impact index based on weighted aggregation of social vulnerability and lack of coping capacities (Right) Top 12 Barangays for socio-economic impact index*

Finally, given the socio-economic impact factor and the physical fire risk index, the overall urban fire risk index is calculated by aggregating based on Equation 1 of the URDI methodology. The map and rankings for the urban fire risk index are presented in *Figure 67*. Again, Tagumpay, Bungdad and Lourdes have the highest fire risk index for the entire city, as they also have the highest physical fire losses for barangays per capita. In fact, most of the top 12 fire risk were also in the top 12 for physical fire impacts. Note: It is unclear how much these results would change if the level of data aggregation were smaller and more consistent, as well as, incorporated IS socio-economic data. As IS areas tend to be the most vulnerable and living in some of the worst conditions, the socio-economic index factor would likely have a more significant role. See Discussion for more details.



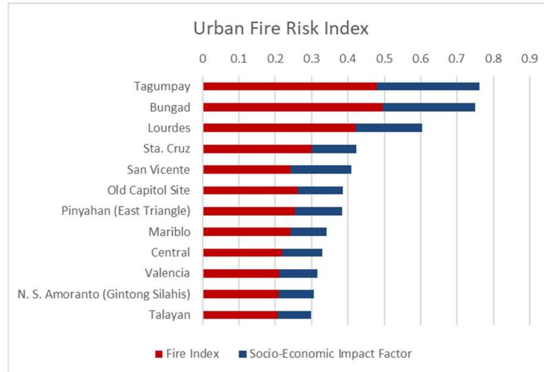




*Figure 67 - (Left) Urban fire risk index based on aggregation of fire impacts and social vulnerability (Right) Top 12 Barangays for urban fire risk index*

# 8 Discussion

Urban fires, particularly in rapidly developing cities in LMICs, are an "everyday disaster" that oftentimes goes underserved in the face of those of the more "lethal reputation" (e.g. earthquake, typhoons, tsunamis) that are not necessarily the most debilitating to sustainable development. This thesis attempts to bring the urban fire problem into the overall disaster risk and sustainable development discourse. The aim is to highlight the significance of IS fires as part of the overall urban fire problem, and further the understanding of the complex, multi-dimensional, aspects of IS areas as they relate to urban fire risk and holistic management of urban disasters in a resource-limited environment. In this study, several quantitative and socio-technical analyses were performed to piece together this understanding.

## 8.1 SIGNIFICANCE OF URBAN INFORMAL SETTLEMENT FIRES – A "DAILY" DISASTER

The statistical analysis at the national level highlighted the importance of fires, relative to other major natural hazards impacting the Philippines. ***Table 15*** summarizes some key metrics in this comparison and highlights that fires, although not the most devastating from an economic or casualty perspective, has a significant impact as the 2$^{nd}$ leading hazard consistently resulting in 100s of deaths (avg = 257), 1000s of injuries (avg = 1026) and 10s of millions USD in economic losses (avg = $87 mill) every year. These impacts alone, but also in comparison to other hazards, provide a compelling case for fires, particularly in urban areas, to be mainstreamed into DRM strategies. The importance of the urban fires was seen in the regional and city-level analysis, where fires were shown to occur more frequently per population (i.e. 2.75 times more often) and have a notable increase in fire risk per inhabitant (i.e. 1.5-2.5x more fire deaths and 2.5x more fire injuries per inhabitant) compared to national averages (See ***Table 9***). It was also seen economically in QC, where annual fires losses accounted for 1% of the GDP and 15% of the annual DRM budget.

*Table 15 – Economic and life losses by hazard (2010-2014) (PSA)*

| Hazard | Occurrences * (5-year period) | Economic Impact | | | | Population Impact | |
|---|---|---|---|---|---|---|---|
| | | Total Loss ($) | Avg. Annual Loss ($) | % of Total | % of GDP | Deaths | % of Total |
| Earthquakes*** | - | $ 320,380 | $ 64,076 | 0.01 | * | - | - |
| Fires | 59,502 | $ 409,380,000 | $ 81,876,000 | 9.25 | 0.033 | 1,253 | 12.1 |
| Flooding | NR | $ 5,634,040 | $ 1,126,808 | 0.13 | * | 125 | 1.2 |
| Typhoon | 30 | $ 3,618,444,120 | $ 723,688,824 | 81.74 | 0.294 | 8,422** | 81.5 |
| Landslides | NR | $ 45,346,340 | $ 9,069,268 | 1.02 | * | 332 | 3.2 |
| Heavy Rain | NR | $ 92,741,000 | $ 18,548,200 | 2.09 | 0.01 | 193 | 1.9 |
| Drought | 2 | $ 3,789,580 | $ 757,916 | 0.09 | * | - | - |
| El Nino | 1 | $ 242,142,500 | $ 48,428,500 | 5.47 | 0.02 | - | - |
| ***Total*** | | ***$ 4,426,924,540*** | | | | ***10,325*** | |

***Neglible, NR = Not reported***
*****Inconsistency in PSA data. Two figures reported (8,422 and 21,698)***
****** Not earthquakes recorded in 2010-2014. Deadliest event in Philippine history resulted in 4,791 deaths in 1976.***

The urban fire significance was seen in the comparison of fire severity to other major cities internationally. In the Philippines, while the fire deaths and injuries per capita were lower, the severity of fire impacts were much greater – i.e. 10x more fire deaths and 2-7x more injuries per fire incident compared to New York and Hong Kong. Unlike other developed cities, the urban fire challenge in the Philippines is only anticipated to grow. This is due to ongoing rural-urban migration to Metro Manila and now other major provincial cities (e.g. Cebu City, Davao City), coupled with the anticipated perpetuation of underlying socio-economic, political and physical inequities that foster fire hazards but also fire vulnerabilities. Based on this data, urban fires are not a thing of the past for the Philippines (and likely other developing cities), but a major "everyday disaster" deserving more attention in the present.

It is interesting to note that while compiling this data, fire statistics/data were consistently addressed separately to all other hazard threats and not considered a "disaster" event. Even in discussions with local DRR managers and barangay officials, who recognized fires as a major issue – if not the most pervasive and resource intensive - still viewed it as an everyday emergency, and therefore not warranting the same level of care/resources as "lethal" hazards, unless as part of a multi-hazard event (e.g. post-earthquake fires). These types of separations in how "disasters" are perceived and managed are not uncommon in DRM literature/practice, and are a result of a variety of reasons – e.g. cognitive biases, institutional fragmentation, historical definitions and perceptions of disasters being natural vs man-made, resource limitations, politics, status of those impacted, lock-in mentality, limited data/information/understanding, etc. In the Philippines, a variety of these issues are likely at play.

But, maybe the real issue isn't that urban fires are not defined as "disaster", but how disaster risks are systemically viewed, managed and operationalized – i.e. from a predominantly hazard-centric view-point, as opposed, to a socio-economic vulnerability issue. That is, there would be little need to fret over being defined as "disaster", where social vulnerabilities and sustainable development (the common origin of all disasters) defined the framework for DRM practices as opposed to a specific set of triggers (Wisner et al. 2004). The focus on human vulnerability is not a new argument and it is not to say that there aren't hazard-specific needs that require unique treatment. It is just to highlight that hazard-centric policies/practices tend to be limiting in scope and divert attention from addressing root causes (Hewitt 1983a; United Nations [UN] & World Bank 2010).

One area of social vulnerability and significant source of "daily" urban fire risk is the prevalence and pervasiveness of large urban ISs. From the statistical and geospatial analyses in this study, IS fires were shown to account for ~23% (1580/6841) of all fires in QC between 2010-2017. Of significance was the high frequency of severe fires (3.9/year) and statically significant clustering of severe fires ($z>2.58$, $p<0.01$) observed in IS areas. This occurred 36.2% and 37%, respectively, of all fire incidents with Alarm Level 1 or greater. Where fires were higher than 5$^{th}$ Alarm level, the occurrence in IS areas went over 76% of incidents.

As seen in Table 16, there were approximately 224 IS fires per year with a rate of increase of 10% annually. Of these, 71% were structural in nature and amounted to 89% of all residential fires in the city. This is substantial as only 30% of the population lives in ISs and means that IS residents are 2.37x more likely to experience a fire than compared to other urban dwellers. From a fire impacts perspective, IS areas are also highly vulnerable – comprising 40% of all deaths, 50% of all injuries and 71% of all fire affected buildings, which is notably higher than the percentage of IS population (30% of total). While IS areas only include 30% of the overall economic losses to fires, loss from a single event (avg. $4,784/incident) likely has a disproportionate impact on IS residents, majority of whom live below or near the poverty line ($4152).

*Table 16 - Summary of key fire statistics for IS areas in Quezon City*

| Thematic Area | Key Informal Settlement Fire Statistic (2010-2017) |
|---|---|
| **Frequency** | • 1,580 fires<br>• 224/year<br>• Increasing at 10% annually |
| **Nature of Fire** | • 23% of all fires ar in IS areas<br>• 71% of all structural fires<br>• 89% of all residential fires<br>• IS residents are 2.37x more likely to experience a fire compared to formal communities |
| **Cause of Fires** | • 47% electrical wiring (”jumpers’)<br>• 17% open flame unattended cooking/stove<br>• 13% open flame candel<br>• 12% electrical applicance |
| **Fire Deaths** | • 40% of all fire deaths<br>• 21 deaths between 2010-2014 |
| **Fire Injuries** | • 50% of all fire injuries<br>• 141 injuries between 2010-2014 |
| **Affected Buildings** | • 71% of all fire affected buildings<br>• 5,366 buildings between 2010-2014 |
| **Financial Impact** | • 30% of total losses<br>• $4,647,424 million between 2010-2014<br>• $4,784 avg loss/incident |
| **Alarm Level** | • 76.9% of all Task Force Level Alarms (n=30) |

These striking statistics speak to the tremendous fire risk that face ISs, but what they neglect are the variety of secondary impacts on health (disability, psychological trauma), environment (water/air pollution from fire debris and contaminated water runoff), social structures, local economies and long-term societal development. These secondary impacts can perpetuate the cycle of socio-economic inequities and vulnerabilities to fires, let alone any other “disaster” or major social “disturbance” (Hummel, 1967). It seems prudent that fires, like other major hazards (natural, man-made, daily, slow-onset, etc.) causing significant social impacts, to be mainstreamed as part of a holistic “disaster” management plan.

## 8.2 COMPLEX, MULTI-DIMENSIONAL UNDERSTANDING OF FIRE RISK IN IS AREAS

As discussed in the beginning of this thesis, obtaining a full appreciation of fire risk in urban IS areas goes beyond the traditional measurements of frequency and physical consequence (albeit an essential component), but in also obtaining a complex understanding of the vulnerabilities and socio-economic underpinnings creating the risk landscape. There are many examples where interventions have been unsuccessful because they did not acknowledge or understand the social contexts (e.g. resource-limited constraints, societal norms/practices/cultures). Thus, several of these aspects were discussed in the introductory sections of this report to gain some understanding of these components, many of which are summarized in *Table 17*.

*Table 17 - Summary of Vulnerabilities in IS areas in Quezon City*

| Vulnerability Thematic Area | Aspects of Vulnerability |
|---|---|
| Physical (Fire Deficiencies) | • Sub-standard, highly combustible, light-weight buildings/housing<br>• Closely spaced buildings (= high fire spread)<br>• Irregular, limited, and narrow means of access and egress<br>• Limited access to "legal" energy for lighting (high frequency of "jumpers")<br>• Higher risk cooking facilities (LGP stoves)<br>• Poor waste management practices<br>• Unknown types and amounts of hazardous and flammable materials<br>• Limited or deficient means of local and/or community-level suppression (e.g. fire extinguishers, water supplies, fire hydrants, fire hoses, sprinklers)<br>• Lack of automatic fire/smoke detection<br>• Limited means of occupant/community notification<br>• Limited fire department personnel/equipment and vehicle access |
| Social | • Social exclusion thru "classism"<br>• Overcrowding and high-density housing<br>• Higher crime rates<br>• Lower education levels |
| Political | • No political voice |
| Economic | • Poverty<br>• Informal economy<br>• Under-employment |
| Access to Services | • Lack of basic services<br>• Open dumping and sanitation<br>• Exclusion from many societal services |
| Legal | • Lack of land tenure<br>• Lack of workers' rights |

These various vulnerabilities are extensive, cut across many sectors and levels of society (individual, city, regional and national levels), and introduce significant complexity to understanding the IS fire problem, let alone developing comprehensive management strategies. Complicating matters is the heterogeneity of socio-economic, human and physical characteristics that not only exist in IS areas across QC but also within a single IS community (Singh, 2016).

In this study, fire service coping capacities and correlations between socio-economic parameters and fire incidents were evaluated to help contribute to this complex understanding of fire risk in IS areas from two different vulnerability perspectives, as well as, inform potential areas of intervention for reducing fire risk. Firstly, *Table 18* provides a summary of the firefighting capacities assessed in this study. As can be seen, firefighting capacities for all services are significantly below international fire standards across the entire city including IS areas. However, the impact of this sub-standard levels will be experienced quite differently in formal vs informal areas.

*Table 18 - Summary of Firefighting Capacities for official BFP services*****

| Firefighting Feature | Level of Feature Required | Level of Feature Provided | % of Performance Criteria (Entire City) | % of Performance Criteria (IS Areas) |
|---|---|---|---|---|
| 1. Firefighting staff | 1469 | 598 | 41% | n/a** |
| 2. Fire vehicles | 105 | 26 | 26% | n/a** |
| 3. Fire Station Response Time *** | 100% of city covered in 4-6 min | 23% of city covered in 4 min<br>44% of city covered in 6 mi | 23% - 44% | 45% |
| 4. Fire Hydrant Spacing | Hydrants spaced 150m apart along a street | 46% of city streets are covered | 46% | 37%***** |
| 5. Fire Hydrant Waterflow Coverage* | All structures should be within 50-100m of a hydrant | At 50m, 7.4% of the city is covered<br>At 100m, 17.6% of the city is covered | 7.4 – 17.6% | 20.4% |

**Informal settlement areas do not comply with fire and building codes with respect to area, use, height, construction materials etc. Thus, there is no prescriptive criteria for these types of spaces. But, based on the expected high challenge fire conditions, the optimum coverage radius would likely be somewhere between 50-100m*

***Staffing and vehicle levels are based on fire station districts which cover several barangays. IS areas are within barangays and therefore subject to same limitations*

**** High traffic conditions are shown as this is the likely conditions majority of the time*

****** Additional volunteer and private fire companies/staff are also located in the city. However, the capacities and capabilities of these services are unknown and not available at the time.

****** As IS areas tend to have narrower streets and unknown levels of obstruction, this is a best guess. The official street shapefile did not appear to have all streets particularly in IS identified. It is unclear if streets/alleys are suitable for fire vehicle access.*

In a well-planned, well-designed and well-regulated city with respect to fire safety standards and building/fire code practices, firefighting resources would be one component of a system of integrated, balanced and redundant design features/engineering systems to prevent and/or mitigate fire losses. The deficiency in this one resource would likely not result in catastrophic failure of the entire fire safety concept. Recall from Annex A.2 that there are six basic concepts/strategies for fire safety engineering (e.g. prevent ignition, control construction, etc.). In a typical building/community designed per fire standards, multiple if not all concepts would be embodied in the design (each with several sub-systems) providing redundancy in the event of loss of one or multiple sub-systems. For the "formal" part of QC which is assumed to be designed to NFPA standards (the locally adopted code), the impact of deficient firefighting resources may not be so severe.

In IS areas, on the other hand, which have not been designed to fire safety standards, the system of redundant fire safety features would be deficient. Annex A.3 and Annex C describe some of the fire safety conditions of a few IS areas in QC (i.e. Novatos, Batasan Hills and Botocan), while also highlighting the heterogeneity of fire safety deficiencies between and within these communities. Notwithstanding the specifics, it is generally understood that by their very "nature", IS areas are lacking fire safety on multiple fronts and that a deficiency in firefighting resources will have a disproportionately greater impact to fire losses in IS areas vs formal parts of the city. This impact is already evident by the percentage (76%) of IS fires that comprise fire incidents reaching Task Force level (i.e. requiring 23+ responding trucks), and the higher rates of injuries/deaths and affected buildings (Refer to Table 16).

For IS areas, firefighting services may be the only means by which to mitigate a fire, once it reaches a certain severity level. Even in the case of Batasan Hills, the local perception is that non-combustible wall construction (i.e. concrete blocks) is sufficient to withstand conflagration. This, of course, is only looking at one sub-system of an overall fire safety concept (i.e. addressing construction), which doesn't provide redundancy or necessarily limit significant fire spread. This is evident from the high concentration of fire losses in Batasan Hills from the hot spot analyses, but also in comparing the building conditions in Botocan which is of a similar standard and yet still experienced a recent fire where over 150 homes were lost (See Section 6.3). Ultimately, the point is that IS areas do not have a balanced and redundant systems of fire safety, and therefore are at greater risk when one system – in this case firefighting resources – are sub-standard.

Secondly, an exploratory regression analysis was undertaken to assess which socio-economic vulnerabilities (including IS characteristics) could help explain fire incidents at the city level, and potentially be targeted for fire risk reduction interventions. However, as was discussed in Section 7.2.5, this portion of the study was not completed. One of the main issues is the inconsistency in barangay areas upon which fire data could be aggregated to align with available census data. This resulted in larger barangays having higher fire counts that did not reflect statistically significant high fire concentration areas. Relatively small areas with high fire and/or social vulnerability profiles are also averaged out across a large barangay. This would not prohibit a regression analysis, but it would mislead urban managers into overlooking problematic high-risk fire areas, which is arguably more critical from a management perspective. These issues are particularly an issue in assessing the role of ISs in the overall urban fire risk problem, since these communities tend not to follow administrative boundaries (e.g. Batasan Hills/Commonwealth/Holy Spirit IS area).

Another major issue is the scale at which census data is collected, i.e. the barangay level, which is significantly larger than the size of IS areas; and the fact that census data is not collected for IS areas due to their "illegal" status. Regression analyses with these data limitations could provide misleading data of socio-economic correlations not reflecting the true conditions and neglect the most vulnerable. Hopefully, the challenges with areal units and limited data at the necessary scale can be addressed in future research, such that the correlations to socio-economic vulnerabilities for IS areas can be verified and targeted for appropriate interventions.

While the regression analysis for IS areas could not be completed (due to data limitations and barangay areal variations), obtaining a complex understanding of city-wide fire risk is still of significant value as a preliminary baseline for developing urban fire management strategies. The URDI approach modified in this study to evaluate fire risk, provides a simplified but holistic, socio-technical model for integrating complex, multi-dimensional aspects of fire risk into a composite indicator for management purposes. It also allows for mainstreaming fire risks into the overall urban disaster risk profile and disaster management strategies for QC as the URDI approach is already adopted for seismic and flood risks. Unfortunately, the URDI approach is also susceptible to the same areal unit issues encountered in the regression analysis. That is, the larger barangays will tend to overly generalize spatial patterns of high fire zones, demographics, socio-economic profiles and vulnerabilities. And, the pockets of high fire risk areas (combination of fire consequences and vulnerable groups) that span across barangay borders will be lost. One way to supplement URDI is to overlay it with the severe fire hot spot analysis (See Figure 68), where areal units can be more localized. This way the high fire prone areas (i.e. IS areas among others) can be captured on the generalized urban fire risk map, and better inform localized management policies and strategies. Note: The proposed fire URDI with severe fire hot spot overlay as a fire risk management tool should be evaluated over time to assess viability and effectiveness at reducing fire impacts given implementation of targeted interventions.

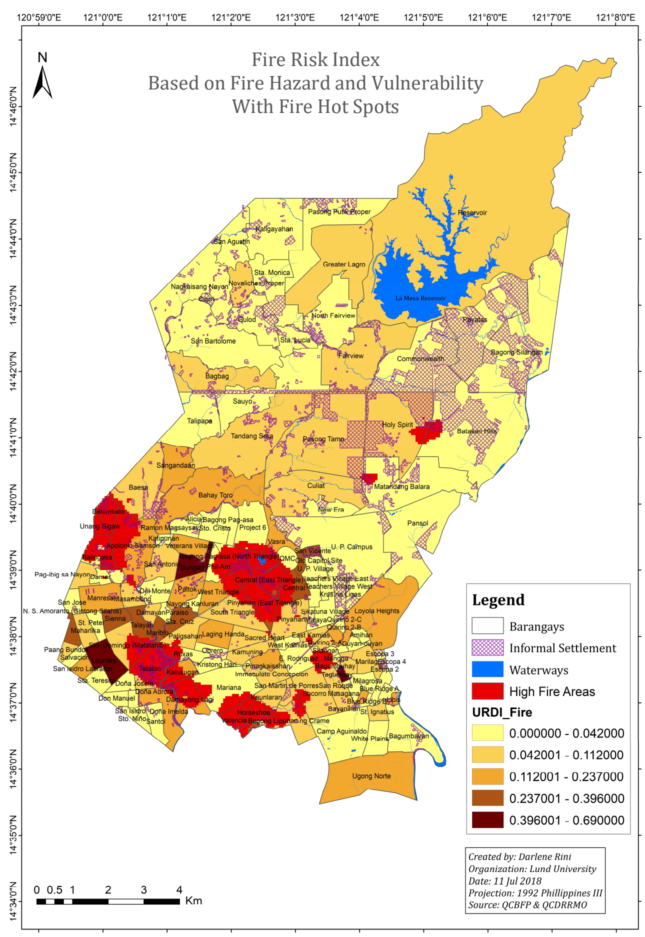



*Figure 68 - Urban Fire Risk Index based on physical fire impacts and social vulnerabilities. Pockets of high fire concentrations from sever fire hot spot analysis is overlaid to better inform targeted fire management strategies*

## 8.3 REFLECTIONS AND FURTHER RESEARCH

Throughout this study, several theories (Annex A) and methods from a variety of disciplines (i.e. statistics, geospatial analysis, urban fire risk indexing) were explored in part to gain a complex, multi-dimensional understanding of IS fires as part of the overall urban fire problem in QC, but also as necessitated by the general lack of literature and data in the Philippines on the subject. The limited and uneven data on fire hazards, impacts and vulnerabilities (socio-economic, physical, legal, etc.) for ISs, let alone at the barangay level or at the city-level made analyzing and understanding the IS fire problem a major challenge. A significant amount of data required modification, compilation from a variety of governmental sources at different levels of administration and cross-validating against several primary and secondary resources. Despite this effort, it was still not possible to make accurate, quantitative conclusions about the specific socio-economic or physical factors that contribute to the increased or decreased fire risk of different IS typologies, let alone between IS areas vs. formal society. Under these circumstances, an exploratory and multi-analytical approach (as adopted herein), is likely the most practical and adaptable framework to gain a complex understanding of the urban fire/IS fire problem in a data-limited environment. These conditions are likely common across many LMICs, and therefore adopting a similar approach may have utility in achieving an increased understanding and holistic management of the urban fire problem.

Regarding the analyses conducted in this report, there are several areas that would benefit from future research. One of the main areas already addressed is the need for census data collection at smaller tract levels than the barangay level, as well as, formal collection in IS areas within this process. This data collection effort would also benefit from collection of fire safety characteristics at these smaller tract levels, such that more fire specific variables can be correlated to fire incident and severity rates. Secondly, future fire statistics, geospatial, spatial and temporal analyses would benefit from a more consistent and completed set of fire data records, inclusion of accurate geo-referencing for fire incidents, and an update on the geospatial/structural changes to IS areas. Many of these data collection and management issues could be resolved by using web-based collection methods and associated training tools (e.g. use of GIS Cloud, Ushahidi).

Another area for future research, particularly where formal datasets and data gathering capacities remain limited, is the use of more community-based, participatory risk and vulnerability assessments for fire risks in IS areas. Some of these approaches include but are not limited to: participatory action research methodology, interviews, focus group discussion, participatory GIS, volunteered geographic information, “citizen science” (Goodchild, 2007/2010/2012). Mixing of these types of bottom-up, qualitative approaches with more top-down quantitative methodologies could provide the necessary complex, socio-technical understanding of the urban fire/IS fire problem in a developing country context, such that more holistic, locally relevant, and sustainable solutions can be developed.

# 9 Conclusions

The studies conducted in this thesis demonstrated the significance of IS fires as part of the overall fire problem in a rapidly urbanizing city in the developing world (i.e. Metro Manila) and increased knowledge in the complex, multi-dimensional aspects of urban fire/IS fire risk to better inform decision-makers in developing more holistic urban disaster risk reduction strategies.

More specific conclusions are as follows:

- Urban fires are among the most common "everyday disasters" faced in Metro Manila. They are the most frequent, and second most devastating hazard with respect to annual deaths and economic losses based on a 5-year review of national disaster events (2010-2014). Because of the "daily" impacts of fires with respect to casualties, damaged housing, economic losses and unknown secondary effects to health, environment, social structures and local economies, fires are arguably the most debilitating to sustainable development.

- In the study area (Quezon City), IS fires comprised a significant portion of the overall urban fire risk, comprising 23% of all recorded fires, 36% of all flaming fires, and 71% of all fires reaching Task Force level between 2010-2017. There were approximately 224 fires/year of which 3.9/year were severe fires with statistical significance ($z>2.58$, $p<0.01$).

- Regarding the nature of IS fires, 71% were structural in nature, amounting to 89% of all residential fires in the city and meaning that IS residents are 2.37x more likely to experience a fire compared to formal neighborhoods. From a fire impacts perspective, IS areas are also highly vulnerable comprising of 40% of all deaths, 50% of all injuries and 71% of all fire affected buildings in the city.

- Due to several limitations in quality and availability of data (i.e. large variations in barangay sizes, small scale of IS areas relative to census data collection areas, and lack of socio-economic and other vulnerability metrics in IS areas), it was not possible to make accurate, quantitative conclusions about the specific socio-economic or physical factors that contribute to the increased/decreased fire risk of different IS typologies, let alone between IS areas and formal society. This is not an uncommon issue in LMICs where data is frequently limited, uneven and inconsistent in availability and management.

- The URDI approach, modified for urban fire risks, provides a simplified but holistic, socio-technical model for integrating complex, multi-dimensional aspects of urban fire risk into a composite indicator for management purposes. However, due to issues with data aggregation at large areal units, localized high fire frequency areas are diffused in the URDI approach. To overcome this issue, overlaying a map of statistically significant "hot spots" is a suggested solution.

- Given the complexity, multi-dimensionality and heterogeneity of the urban IS fire issue in the overall urban fire risk problem and local data limitations, the adaptive multi-analytical approach adopted in this study would be significantly enhanced by integration of qualitative methods (e.g. interviews, focus groups), as well as, bottom-up approaches (e.g. participatory action research methodology, participatory GIS, VGI, "citizen science"). Mixing of bottom-up, qualitative approaches with more top-down quantitative methodologies could provide the necessary complex, socio-technical understanding of the urban fire/IS fire problem in a developing country context, such that more holistic, locally relevant, and sustainable solutions can be developed.

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# ANNEX A. Detailed Theoretical Framework

## A.1 FIRE RISK AND VULNERABILITY

The concept of risk has been developed over many centuries and across many fields of research, including engineering, health, economics, business management, political science, sociology and psychology. As such, there are numerous perspectives on risk and therefore no commonly accepted definition (Meacham, 2004; Ben-Ari & Or-Chen, 2009; Moller, 2012; Aven & Renn, 2009). In engineering, managing risk has traditionally been from a technical and more "objective" perspective defined by the probability and frequency of a hazard event, exposure of people and property to that hazard, and the consequences of that exposure (Renn, 1998; Tehler, 2010; Wamsler, 2014, SFPE Handbook, 2002). While it can take many forms, traditional risk frameworks adopt a "hazard-centric" focus whereby the main triggering agent, oftentimes of a "natural" event, is quantified with respect to intensity and severity on physical causal mechanisms. While this knowledge is important and provides valuable information, many, social scientists, would argue that this technical view is insufficient in understanding the actual level of risk and therefore leads to solutions (oftentimes technocratic in nature) that don't address root causes (Wisner, 2004; Bradbury, 1989: Morin et al, 2016).

The contemporary view of risk is shaped not only by the triggering event or hazard (natural or man-made), but also by the vulnerabilities (e.g. social, physical, economic, environmental, psychological, health, mobility, legal, resilience, security, political, access) people have to that hazard (Wisner, 2004; Blaikie et al., 1994; Jasanoff, 1998; IFRC, 2006). Vulnerability is defined as "the degree to which a community is at risk from the physical phenomenon and the socio-economic factors that affect the capacity to absorb and recover from a hazard event" (Westgate and O'Keefe, 1976). These vulnerabilities are socially constructed, multi-dimensional, and shaped not only by history, politics and culture, but also by uncertainty, coping capacities, resiliency, adaptation and capital accessibility of individuals, communities and governments over time (Wisner, 2004; Jasanoff, 1998; Pamungkas, A, 2012; Birkmann, 2006; Becker, 2014). That is, vulnerability is a result of progressive underlying causes and pressures (i.e. pressure and release model) trickling down from the global to local level, as well as, limited access to capital – human (e.g. skills, knowledge), social (eg networks, groups), physical assets (tech, equipment), natural (resources, land, water) and financial capital (Morin et al, 2016). Thus, risk is a broad and complex concept requiring different perspectives to achieve a complete understanding, and ultimately to serve as a basis for decision-making in developing long-term, sustainable strategies for development and disaster risk management.

Within the urban fire context, risk concepts have been integral to fire research and fire engineering since the 19$^{th}$ century as formal fire risk assessments evolved with the insurance industry (SFPE, 2002). Much of these concepts and applications, however, have been concentrated in the developed world (Balahadia, 2015; Zhang, 2018). That said, the current state of urban fire safety in practice is primarily based on prescriptive codes/standards without the explicit use of quantified fire risk methods. Even with prescriptive designs, every design decision is a risk decision embodied in the building/fire codes where acceptable levels of safety for individuals and society are set using various risk concepts (Sekizawa, 2005; Beck, 1994; Yung, 1997; Clarke, 1990; Hall ,1992; Ebihara, 2000; SFPE Handbook, 2005; Dungan, 2001; Meacham, 2001; Wolski, 2001). In practice, a range of quantitative and qualitative methods – ranging from hard data to science to expert judgement – are used depending on the level of sophistication deemed necessary and appropriate to meet objectives

(SFPE, 2002). Checklists, narratives, indexing and more increasingly deterministic (e.g. fire modelling, smoke modelling, egress simulations) and performance-based methods are considered the most common approaches undertaken in practice. Probabilistic methods, while used for decades in specific industries (e.g. chemical processing, nuclear, transportation), remain rare (SFPE, 2002; Bukowski, 2006; NFP 2001). While fire risk has historically taken the more traditional, objective view of risk, there are increasing applications of a more contemporary view that includes aspects of societal vulnerability and coping capacities (Zhang, 2013, Cardona, 2009; Corcoran et al, 2011; Jennings, 2013).

## A.2 FIRE SAFETY ENGINEERING

Fire safety engineering, as defined by the Building Research Establishment (BRE), is "the application of scientific and engineering principles based on the understanding of the effects of fire, the reaction and behaviour of people to fire and how to protect people, property and the environment." In practice, fire engineering is a process of achieving integration, balance and redundancy of various systems (e.g. technical, operational, physical, social, psychological) to prevent and/or mitigate the negative impacts of fire (Cote, 2003; Watts, 2003). That is, fire safety engineering incorporates many different design features and systems to achieve the desired performance outcome using various strategies. The basic fire safety concepts/strategies are summarized in ***Table 19***.

*Table 19 - Basic fire safety strategies/concepts and sample design interventions*

| Fire Safety Concepts | Sample Applications/Interventions |
|---|---|
| Prevent Ignition | • Separate potential heat sources from potential fuels<br>• Occupant fire safety education<br>• Operational procedures and maintenance of equipment, heating/electrical systems, cooking/refrigeration systems, etc.<br>• Security (arson/misuse prevention)<br>• Fuel load and heat source controls |
| Control Combustion | • Minimize flame spread and smoke development via material choices for construction materials and interior finishes<br>• Fuel load control (i.e. quantity, type of materials, distribution of contents)<br>• Air supply/HVAC control, smoke control systems<br>• Size, shape and construction of rooms<br>• Vertical and horizontal opening design (e.g. shaft and opening protections) |
| Construction Materials | • Fire resistant and/or non-combustible materials for structural building |

| | |
|---|---|
| | components to limit fire spread and/or collapse.<br>• Thermal resistance and integrity of construction elements (walls, floors, partitions) to limit fire spread |
| Detection and Notification | • Automatic or manual fire detection systems of smoke, heat and flames<br>• Automatic or manual alarm notification systems for occupant fire safety and fire department response |
| Suppression | • Manual suppression (e.g. fire extinguishers, hose reels, internal hydrants)<br>• Automatic suppression (e.g. sprinklers, foam, gaseous systems)<br>• Firefighting provisions (e.g. external/internal hydrants, fire department vehicle and personnel access) |
| Manage the Exposed | • Evacuation (e.g. means of egress systems, doors, protected stairs, exit passageways)<br>• Defend in Place (e.g. fire rated enclosures, compartmentalization of building in fire zones)<br>• Refuge (e.g. horizontal exits, fire rated enclosures/floors/spaces) |

*Source: NFPA Handbook, 2003*

These basic concepts are integral to fire safety engineering/design and are incorporated in most building and fires codes, as well as, performance-based codes and standards around the world (e.g. International Building Codes, NFPA 101, NFPA 5000, Approved Document B).

Since fire risk is a spatial and temporal process at different scales (e.g. room, floor, building, city), the causative and consequence factors should be assessed and then managed spatially, temporally and at varying scales. While most urban fire safety challenges/designs have generally been addressed at the building scale, no consensus approach has yet been developed to assess the interaction of fire safety risks (physical, technical, social etc.) at the city scale. This may be possible with GIS techniques and assessing the applicability of approaches from other disciplines (e.g. wildland fire, social sciences, naturally-induced disaster, complex systems theories)

## A.3 URBAN INFORMAL SETTLEMENTS AND MULTI-DIMENSIONAL POVERTY

According to UN-Habitat (2003), 'slums' (aka informal settlements, squatters, depressed areas, homeless and underprivileged, shanty towns, townships, favelas, ghetto, bidonvilles, barrio marginal, kampungs) describes a wide range of low-income settlements and/or poor living conditions where "inhabitants suffer one or more of the following household deprivations: lack of access to improved water source, lack of access to improved sanitation facilities, lack of sufficient living area, lack of housing durability and lack of security of tenure." This definition while encapsulating some of the essential characteristics of slums – limited capital resources (e.g. services), physical criteria (i.e. high density, low standard housing) and security (e.g. tenure) – others would argue that it's missing social and behavioral criteria such as skills, knowledge, social networks, social cohesion, physical assets, and financial capital (UN-Habitat, 2010; Porio, 2011). This definition, coupled with the numerous others in the literature (Cities Alliance, 2006; Gilbert, 2007; Cruz, 2010; Morin et al, 2016), reflects the complex, heterogeneous, multi-dimensional characteristics that slums embody around the world and the difficulty in reaching a single, universally agreed definition (UN-Habitat, 2010). Difficulties also arise because "slums" are often viewed as a relative concept, variations in characteristics at the country/city or even within the same slum are wide, and the conditions of slums can change in time and space (UN-Habitat, 2010; Morin et al, 2016; Aldrich, 2016). So, defining operational limits/criteria for each characteristic, particularly for social aspects, is no easy task for governments. In the Philippines, slums are simply defined by lack of land tenure or "rent free without consent of owner" (Morin et al, 2016; Cruz, 2010).

***Table 20*** provides a list of some common characteristics of slums found in the literature. Slum households may experience any number of these dimensions of deprivation, which further exacerbates the experience of income poverty (Singh, 2017).

*Table 20 – Common characteristics of slums as reflected in the literature*

| Characteristic | Sample Features |
|---|---|
| 1. Lack of basic services | More common:<br>• Lack of improved sanitation facilities<br>• Lack of improved water sources<br>Less common:<br>• Absence of waste collection<br>• Absence of electricity supply<br>• Absence of surfaced roads/footpaths<br>• Absence of street lighting<br>• Absence of rainwater drainage |
| 2. Substandard housing or illegal and inadequate building structures | • High number of substandard housing structures<br>• Built with non-permanent materials unsuitable for housing in location conditions (climate, location)<br>• Earthen floors, mud-and-wattle walls, native grass roofs<br>• Violation of many building standards/codes |
| 3. Overcrowding and high density | • High occupancy rates<br>• Cohabitation by different families<br>• High number of single room units<br>• 5+ person per single room for cooking, sleeping and living |

| | |
|---|---|
| | • Size of homes (sq.m) varies from location to location |
| 4. Unhealthy living conditions and hazardous locations | • Lack of basic services<br>• Open sewers<br>• Lack of pathways<br>• Uncontrolled dumping of waste<br>• Polluted environments<br>• Susceptibility to diseases and illness<br>• Houses built in hazardous locations (floodplains, toxic/industrial areas, waste areas, fault-lines, landslide zones, waterways, rail lines, utility zones) |
| 5. Insecure tenure; irregular or informal settlements | • Lack of title, right to occupy land or structure<br>• Non-compliance with land-use plans |
| 6. Poverty and social exclusion | • Income or capability poverty<br>• Under- or un-employment<br>• Informal economy (economic insecurity)<br>• Social and physical exclusion, "classism"<br>• High crime<br>• Lower levels of knowledge, skills<br>• May have high numbers of immigrants, minorities, displaced persons |
| 7. Minimum settlement size | • Minimum area (e.g. 700 sqm) for several houses/shack or number of people (e.g. 300 people or 60 households) |

***Sources: UN-Habitat, 2010; Morin et al, 2016; Garrido, 2013; Singh, 2017; Cruz, 2011***

In Metro Manila, informal settlements are characterized by some or all these features. Figure 69 summarizes the main issues identified in a survey conducted by the World Bank, 2016.

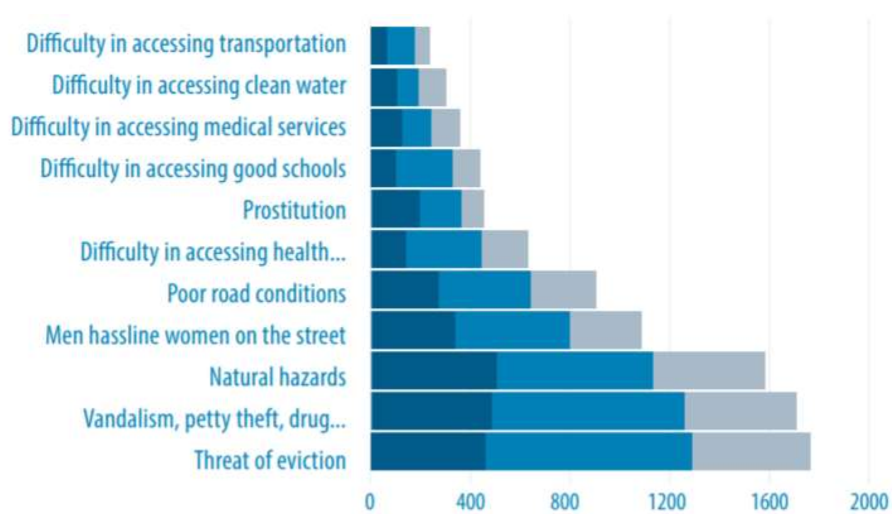



*Figure 69 - Issues Faced by Informal Settlers in Metro Manila (World Bank, 2016)*

However, unlike major urbanizing cities in other countries (e.g. South Africa, Pakistan, China, Brazil), the settlement pattern of Metro Manila poor is generally dispersed and not so geographically segregated or of consistent built environment characteristics (See Figure 70). Houses are located wherever there is space and opportunity in many cases along waterways, rail lines, flood plains, utility zones, seismic fault lines, vacant private/public land and even within “formal” communities (Singh, 2017; Garrido, 2013; Cruz, 2011). The conditions in slums vary widely (in features and severity) across the city and within an individual slum area itself (Porio, 2011). For example, in a case study in Novatos (one of 17 cities in Metro Manila) of around 60,000 informal settlers, the settlement had consistent housing characteristics – medium density patches of homes constructed of make-shift materials (e.g. sheet metal, wood, plastics) built-upon wooden stilts (Morin et al, 2016). However, households exhibited large variations in asset and resource levels ranging from abject poverty to middle-class (Morin et al, 2016). In a slum in Quezon City housing was of low-density and constructed primarily of concrete walls/floors with sheet metal roofing with a dependency ratio of 57 compared to 75 in Novatos (Singh, 2017). In both locations, basic services (e.g. electricity, water) and employment, although not necessarily provided via ‘formal’ systems, was accessible via ‘informal’ systems for nearly all households. And in both locations, residents were acutely aware of disaster risks, as they are part of everyday life (Morin et al, 2016; Singh, 2017).

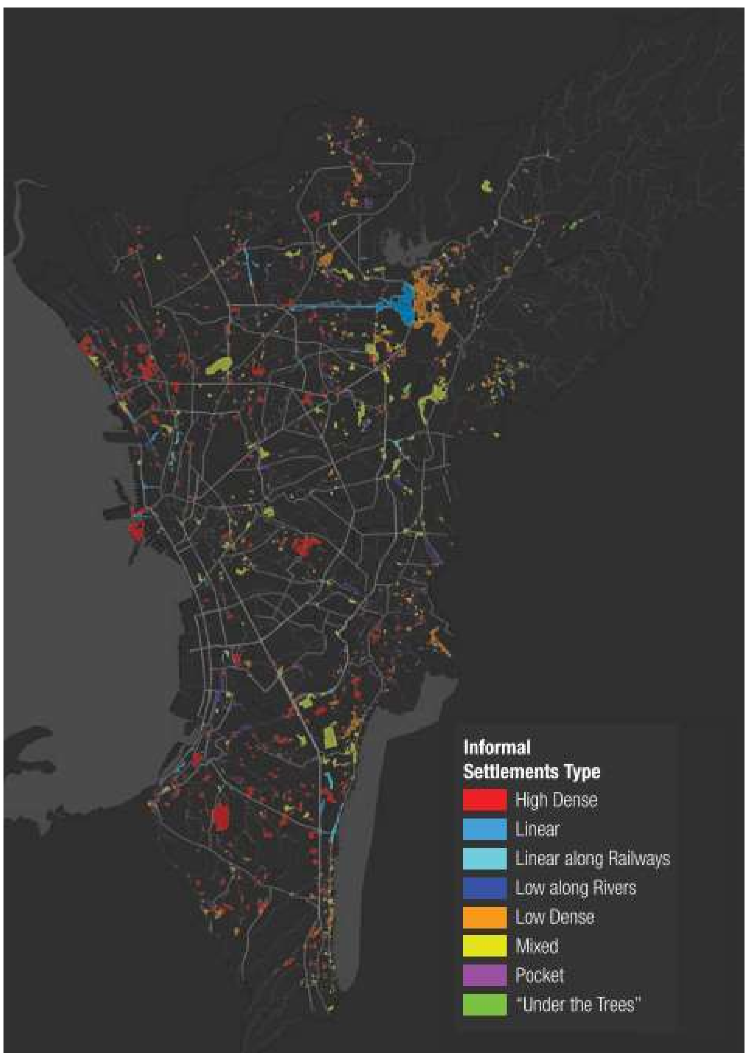



*Figure 70 - Variations in the typology of ISs in Metro Manila. In a study sponsored by the World Bank, GIS and satellite imagery was used to categorize the various types of built environments within the metropolis. Unlike other cities in other countries, the informal settlements in Manila are dispersed throughout the region with large variability in physical, social, economic and political vulnerabilities and exposure risks. (Singh, 2017)*

Some of the root causes and conditions found in ISs in Metro Manila can be traced back in history. The formation of these communities started in the late 16th century during Spanish colonialization. The city was established, like many other European colonialized cities, as a twin city with a European core of stone buildings around which spread a much larger indigenous periphery of bamboo, nipa palm and other native grass structures (Bankoff, 2012; Morin et al, 2016). During this time, fires as well as earthquakes were a constant threat, a way of life and a catalyst of social and physical changes in the shaping of the city. How these threats were managed were also a reflection of the dichotomy in socio-economics and ethnic realities (e.g. the wealthy Spanish core incorporated building regulations, wider streets, fire-fighting provisions; while indigenous housing areas went unregulated/underserved). Different levels of risk acceptance and adaptation between the indigenous and the colonizers were also accepted and perpetuated – e.g. the indigenous area could burn down, while the Spanish area was protected and preserved (Bankoff, 2012). These historical exclusions continued into the 20th century when informal communities came to be called “slums” and contemporary issues of globalization and neo-imperialism emerged to further exacerbate conditions (Alcazaren etl al, 2011; Hanrahan, 2015). It is within this modern context of rapid urbanization, neo-liberalism and globalization that the informal settlement population of Metro Manila skyrocketed with more than 600,000 households (4.5 million people) or roughly 30% of the city’s population (NEDA, 2011).

Beyond the main drivers of rapid urbanization and lingering colonial impacts, several post-independence policies and practices in the Philippines have contributed to the growth of the informal settlement problem via push-pull mechanisms (Morin et al, 2016). This included increased pressure on land (conversion of agricultural land for other uses), rural un- and under-employment, rural-urban income disparity, and concentration of agricultural land ownership in the hands of a few wealthy elite, all of which “pushed” farmers and rural inhabitants to the cities for greater opportunities (Kahl, 2006; Ahmed, 2014. Industrial growth, export-oriented manufacturing created in pursuit of a global, modernizing economy served as a “pull” factor in rural-urban migration for the promise of better jobs and living standards (Morin et al, 2016; Ahmed, 2014). These push-pull factors coupled with increased demand/price for land, failed urban planning (in basic services, infrastructure, affordable housing), corruption (particularly during the Marcos era), all contributed to the growth of ISs and urbanizing the poor. These underlying policies and the inability to accommodate the large influx of rural-urban migrants also led to the formation of a large informal economy (Singh, 2017). This tertiary economy while providing high-employment rates for informal settlers, only further exacerbates vulnerabilities due to lower wages, insecure employment, exploitation, and deprived social and legal safety nets (Singh, 2017). And, because this system supports neo-colonial, neoliberal policies, political will to facilitate pro-poor policies and eradication of ISs is weak (Davis, 2006; Berner, 1997; Collins and Jimenez, 2012).

Since the rapid growth of informal settlements in the early 1900s, government officials have made attempts to eradicate slum areas and address the housing crisis. The approaches ranged from criminalization of squatting (Presidential Decree 772), forced evictions, out-city relocations, socialized housing and, in some cases, granting of land rights (Morin et al, 2016). Many of these solutions failed, as they did not benefit informal settlers and failed to address the underlying social, economic, legal, and political drivers (e.g. social injustice, inequities, inequitable distribution of resources and income, power relations/segregation) that depend on cheap labor and maintaining existing power structures but cannot provide for adequate housing and resources (Alcazaren et al;

Laquin, 1971; Berner, 2001). Land acquisition solutions, while successful, lacked the scale to be broadly effective (Teodoro and Rayos, 2009).

Urban ISs in Metro Manila present a complex, dynamic, non-homogenous and multi-dimensional challenge. Threat of eviction, demolition and a wide variety of other socio-economic (crime), legal, livelihood and other health pressures, are only further compounded by the ongoing threat of natural and man-made disasters. Fires, as in the past, still tend to be a major concern for the metropolis particularly as people, properties and urban resources are more densely concentrated and intertwined. Thus, formal assessment of the urban fire problem of the "twin city" of formal and informal enclaves necessitates a broad range of perspectives at various levels of abstraction over historical and modern contexts, as well as, recognition of the complex set of barriers influencing the status quo (See *Table 21*)

*Table 21 - Underlying Factors/Barriers Influencing Informal Settlements in Metro Manila*

| Thematic Area | Key Issue |
| --- | --- |
| Administrative | • Urban planning issues due to rapid urbanization<br>• Insufficient low-income, in-city housing<br>• Enforcement issues (clearing of illegal squatting, preventing settlements in high hazard areas) |
| Social/Cultural | • Perceptions (risk, distrust in government, "classism")<br>• Corruption<br>• Socio-economic limitations<br>• Psychological attachment to IS areas |
| Political | • Limited and/consistent political will |
| Legal | • Squatter's rights<br>• Limited legal/policy/institutional frameworks |
| Technical | • Limited local capacities (hard/soft capacities in fire engineering, fire risk awareness)<br>• Technical limitations (e.g. knowledge, analytical skills, equipment, technology)<br>• Insufficient public transportation |
| Environmental | • Tyranny of the urgent (i.e. seismic, typhoons) |
| Economic | • Overburden and over-stretched from other ongoing disaster and climate change risks<br>• Neoliberal policies relying on IS economy |

## A.4 COMPLEXITY THEORY AND SYSTEMS PERSPECTIVE

Modern cities are often described as highly complex, self-organizing systems. That is, they are comprised of many different constitutive parts and subsystems (from infrastructure to technology to environmental impacts to social dependencies) with dynamic interactions, interrelations and interdependencies (Jacobs, 1961; Becker, 2014). As the interacting parts engage and compete in non-linear ways, they often give rise to feedback loops making causal-effect relationships difficult to determine and can lead to unpredictable rippling effects (i.e. "butterfly effect") with disproportionate impacts over space and time. In complex systems, individual actors/agents are not able to have full knowledge and/or ability to control the global system but can influence all parts – i.e. the principle of locality (Becker 2014, Bergstrom 2014, Heylighen et al 2006). Because of these local interactions, global characteristics emerge for the whole system that are not intrinsic to nor can be easily inferred from the constituent parts (Heylighen et al 2006). This network of relations, which is central to the complexity theory, cannot be easily explained, quantified, or predicted through simple linear relationships or reducing the system to the study of individual parts. Each individual component is integral to the system, but each is influenced by its own set of characteristics, values, perspectives, rules, etc., which introduces uncertainty of how each component influences the whole.

Complexity alone, however, is not the sole accomplice in the changing character of risk and vulnerability in today's urban world. Trends in globalization, industrialization, increased dependencies on technology/science/internet-of-things, institutional fragmentation, increased complexity of technology, among other interrelated phenomena are also key players in changing the risk landscape (Hassel, 2007). Today, natural and man-made hazards have the potential to cause widespread harm at all levels of society, in sometimes unpredictable and unexpected ways. A part of this is due to the socio-technical nature that many urban challenges, such as the IS fire problem, present. That is, they contain or involve components and sub-systems that are technical (e.g. building safety, infrastructure, services, utilities, etc.) and social (e.g. individuals/actors/groups/organizations, behavioral science, poverty, access to social capital, psychology). All these various components are complex systems, unto themselves, and so trying to understand each component, let alone the whole system, has led many to decompose and reduce research down to studies of single parts (Heylighen et al 2006; Checkland, 2006). However, in complexity science, this approach is viewed as obtuse and susceptible to overlooking central characteristics unique to the system as a whole.

Taking from these concepts in complexity science, this thesis attempts to explore the complex nature of fires in urban ISs from top-down and bottom-up perspectives (although not presented analytical herein) using quantitative and qualitative data (Mahibar, 2016). While little research has been conducted using complex modelling tools (e.g. cellular automata, agent-base models, interacting state machines, genetic/particle swarm approaches) to understand and predict the nature of fires in slums, approaching the problem with the spirit of complexity science – i.e. with a multiple systems or socio-technical, multi-variate perspective – may provide a more holistic view, leading to more sustainable, effective and integrated urban disaster risk management strategies (Jennings, 2013).

## A.5 DISASTER RISK MANAGEMENT

Disaster risk management (DRM) is the process to "minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development" (UNISDR, 2004:17). However, DRM is a highly complex, multi-dimensional process that cuts across many sectors and levels of society and is invariably linked to sustainable development. Many challenges faced by disaster risk managers stem from underlying developmental issues and vulnerabilities across a broad range of societal aspects – social, political, environmental, economic, historic, etc. These inter-relationships are complex, dynamic non-linear networks of multiple cause and effect relationships that are not readily understood and/or addressable (Becker, 2014). Because of this complexity, DRM and sustainable development necessitate a complex understanding by engaging in a broad range of perspectives for a sustainable, safe and resilient society (UNISDR, 2015/2; CRED, 2016) and applying various strategies - prevention, mitigation, response and recovery – from a holistic, systems perspective, not just from a technocratic, reactive angle.

# ANNEX B. Detailed Methodology

## B.1 PART I – LITERATURE REVIEW

A literature review was conducted throughout the duration of the research project. The review was based on scientific journals, research papers, government reports, official reports/guidelines, books, book chapters and private practice documents. The initial aim was to identify the current state of knowledge and practice – methods, policies, programs, applications, guidelines – for understanding and managing fire risks of urban informal settlements as part of urban disaster risk management, particularly, in the context of LMICs. The literature was selected from the following sources:

(1) Scientific databases (i.e. LUB Search and PHI, EBSCOhost)

(2) Google Scholar

(3) Google search engine

(4) ISI Web of Science

(5) Scopus Direct

This initial literature search was performed using specific keywords and other related terms, such as slums and fire, informal settlements and fire, slum fire risks, slum fire incidents, shack fires, urban poverty and urban fire risk. In addition, cross-referencing (i.e. "snowballing") was used to identify additional literature. These were skimmed to pinpoint the most relevant sources for more in-depth review (cf. Booth, Colomb & Williams, 1995). The disciplinary scope of the literature review included DRM, urban studies, international development, engineering, public administration, information science, and computer science.

Note: A significant amount of background material was also collected to understand the relative significance of the urban IS fire risk challenge in the overall context of DRM, as well as, the methods/approaches used for other non-fire hazards/risks management processes. For example, the type of material included risk, fire risk assessments, risk and safety management, fire statistics, geospatial statistics, fire hazard mapping, GIS and fire mapping, fire engineering, fire risk indexing, slums, poverty, urban disaster risk, wildfire management, and urbanization.

## B.2 PART II – INTER-DISCIPLINARY ANALYSES

### B.2.1 A Case-Study Approach

The inter-disciplinary analyses presented in the following sections were undertaken using Quezon City – one of the 17 cities comprising Metropolitan Manila – as a case study. The case study approach was adopted to better manage the scope of the complex and dynamic hazard of fire safety in a mega-city environment, not only from a technical fire engineering perspective, but also from the diversity of the underlying and interrelated socio-economic, political, legal challenges, as well as, the breadth of stakeholders involved. The case study approach also allows for the evaluation of the problem from a variety of sources and in greater detail, providing a more complex and nuanced understanding (Yin, 2003).

Selecting Quezon City was determined during a 6-month exploratory in-country field study. Because of its rapid growth and urbanization, Quezon City has the largest IS population per capita in the

Philippines (QCDRRMO, 2013/2), and over the past few decades, experienced some of the most severe IS fires (e.g. Botocan fire on March 5, 2018 which resulted in the loss of 200 homes and displaced 5,000 residents). Despite having the largest IS population in Metro Manila, Quezon City because of its size and growing economy, also has one of the most well-funded disaster risk reduction management offices and emergency response networks in the capital region (QCG, 2017). These features provided many sources of information, perspectives and incident data to study and evaluate for the project.

### B.2.2 Data Collection

Data for this study was collected from a range of local, national and international sources. National-level and Regional-level data for fire incidents, population, demographics, revenue, other disaster events, etc. was collected from the Philippines Statistics Administration (PSA). Local Quezon City data – fire incident data, emergency management asset data, administrative data, land-use data, hydrological data, built environment data, high hazard facilities data, demographics data and aerial photographs – was provided by the Quezon City Disaster Risk Reduction Management office (QCDRRMO), the Quezon City Bureau of Fire Protection (QC BFP) and Barangay Captains (Batasan Hills and Botocan). **Table 22** provides a summary of the collected data and the respective sources.

***Table 22 - Data Collection and Sources***

| Thematic Data | Format | Year of Data | Source |
|---|---|---|---|
| ➢ Fire incident<br>Fire losses | Excel (.xls) | 2010 – 2017 | National and Regional Data – PSA<br>Quezon City Data – QC BFP |
| ➢ Administrative boundaries | ESRI ArcView Shapefile (.shp)<br>Polygon features | 2010 | National and Regional Data – PhilGIS<br>Quezon City Data – QCDRRMO |
| ➢ Population | ESRI ArcView Shapefile (.shp)<br>Polygon features | 2000, 2007, 2010 | National and Regional Data – PSA<br>Quezon City Data – QCDRRMO, Barangay Batasan Hills Captain and Barangay Botocan Captain |
| ➢ Emergency management<br>- *Fire & police stations*<br>Critical facilities<br>- *Hospitals, healthcare, power stations*<br>Built environment<br>- *Barangay halls & IS*<br>High-hazard facilities | ESRI ArcView Shapefile (.shp)<br>Polygon features | 2010 | Quezon City Data – QCDRRMO |
| ➢ Roadways | ESRI ArcView Shapefile (.shp)<br>Line features | 2010 | Quezon City Data – QCDRRMO |
| ➢ Land-use<br>Hydrology<br>Open spaces | ESRI ArcView Shapefile (.shp)<br>Polygon features | | Quezon City Data – QCDRRMO |
| ➢ Firefighting facilities and resources (i.e. stations, staff, trucks, hydrants) | Excel (.xls) – staff and trucks, hydrants, fire stations | 2017<br>2010 | Quezon City Data – QCDRRMO & BFP |

| | | | |
|---|---|---|---|
| | ESRI ArcView Shapefile (.shp) – fire station locations<br><br>PDF file (.pdf) – hydrants | 2017 | |
| ➢ Aerial photographs | Portable document format (.pdf) | 2018 | QCDRRMO |
| ➢ Demographics<br>Revenue (annual) | Excel (.xls) – Revenue<br><br>ESRI Arcview Shapefile (.shp) – Population, Growth rate | 2010 | National and Regional Data – PSA<br><br>Quezon City Data – QCDRRMO |
| ➢ Elevation | ESRI ArcView Raster | 2010 | Quezon City Data – QCDRRMO |
| ➢ Urban Disaster Risk Index (Earthquake & Flooding, and socio-economic factors) | ESRI ArcView Shapefile (.shp)<br><br>Polygon features | 2013 | Quezon City Data – QCDRRMO & EMI |

### B.2.3 Statistical Analysis

As a starting point for characterizing the fire problem in informal settlements, a descriptive statistical analysis using a top-down approach was undertaken (Ahrens M., Frazier P, Heeschen J., 2003). The top-down approach evaluated fire statistics at the national-, regional- (i.e. Metro Manila) and city-level (i.e. Quezon City) to understand the size of the fire problem relative to other non-fire related hazards (i.e. earthquakes, typhoons, flooding) and to assess basic characteristics/qualities and trends of the fire data. **Table 23** provides a summary of the descriptive statistics assessed over a 10-year period (2006-2017).

Table 23 – Fire Statistics Collected

| Fire Feature | Fire Statistic Collected |
|---|---|
| 1. Fire Incidents | • Total number of fire incidents<br>• Frequency of fire incidents per ha<br>• Trend in number of fire incidents (i.e. min, max, average, % change, standard deviation)<br>• Total fire incidents per 100,000 people<br>• Total fire incidents per month/per time of day<br>• Trend in fire incidents vs. population change<br>• Total fire incidents in NCR vs. national totals (%)<br>• Total number of incidents per 100,000 people vs. other countries data |
| 2. Casualties* | • Total and average number of deaths and injuries<br>• Total number of deaths per 100,000 people<br>• Deaths by age (nationally only)<br>• Total casualties in NCR vs national totals (%)<br>• Total number of deaths per 100,000 people vs. other countries data |
| 3. Direct Damages | • Total estimated damages in USD<br>• Total average loss (in USD) per fire incident**<br>• Total estimated damages vs. GDP |
| 4. Nature of Fire | • % of structural, non-structural, and vehicular fires |

| | |
|---|---|
| | • % of structural fires by occupancy |
| 5. Sources of Ignition | • % of sources of ignition |
| 6. Temporal Characteristics | • % of fires by month<br>• % of fire by time of day |
| 7. Fire Incidents vs. Other Disasters | • % of deaths by disaster<br>• % of total damages by disaster |

***QC Data only available for 2013-2017***

****Nationally only available from 2010-2017; NCR for 2016/2017; QC for 2013-2017***

Note: As is the case in many developing countries, fire data collection can be inconsistent, limited, and/or missing. While the BFP fire data collection system is collected at various levels of administration (national, regional, city, and barangay), there is still large variability in how the data is collected at the barangay and city level, and how easily data can be obtained. This introduces some uncertainty in the data/analysis, some of which was removed during pre-processing of the data prior to analysis in Section B.2.4.1. Refer to Limitations section for additional discussion.

### B.2.4 Geospatial Analysis and Mapping

The geospatial analysis of fire data for Quezon City includes a variety of spatial, temporal and spatiotemporal techniques to assess basic descriptive fire statistics, spatial fire patterns, geospatial fire statistics, data correlations and fire service coverage areas. The analyses were performed using ArcGIS 10.5.1 – a geographic information system (GIS) tool that integrates hardware, software, and data for capturing, managing, analyzing and displaying all forms of geographically referenced information (ESRI, 2011). A summary of the various geospatial analyses performed in this study is provided in ***Table 24***.

*Table 24 - Summary of geospatial analyses undertaken for Quezon City fire data*

| Objective | Analytical Techniques Employed in ArcGIS |
|---|---|
| 1. Descriptive Fire Statistics | • Mapping of all fire incidents and sub-categories of fires (structural, non-structural, vehicular, IS fires)<br>• Mapping of fire impacts (deaths, injuries, damaged homes, $ losses)<br>• Generate statistics<br>• Select by Attribute for alarm level statistics and relation to IS areas |
| 2. Simple Spatial Patterns | • Fire point density and kernel density (all incidents)<br>• Overlay "heat maps" with IS shapefile layer |
| 3. Simple Temporal Analyses | • Mapping of kernel density by year<br>• Select by Attribute fire incidents by time of year and time of day (presented in statistical analysis section) |
| 4. Geospatial and Temporal Fire Statistics | • Hot spot analysis (Getis-Ord) of all fire incidents<br>• Hot spot analysis by fire alarm level (proxy for severity)<br>• Hot spot analysis by fire alarm level (2010-2017) and (2013-2017)<br>• Hot spot analysis for severe fires only (2010-2017) |

| | |
|---|---|
| | • Clustering analyses (Spatial autocorrelation) of all fires, sub-categories of fire, fire impacts (deaths, injuries, financial losses) |
| 5. Data Correlation | • Exploratory Regression analysis to assess correlation or importance of various social, economic, physical, and technical parameters |
| 6. Fire Service Coverage Areas | • Mapping of fire services (stations, barangay halls, hospitals, medical facilities). Spatial join to barangay admin layer.<br>• Simple point buffer analysis to assess fire flow coverage<br>• Spatial network analysis to assess fire hydrant spacing coverage<br>• Spatiotemporal network analysis for fire station response time coverage |

#### *B.2.4.1 Data Processing for GIS analyses*

The fire incident data collected for Quezon City spanned between 2010-2017 and contained 6,841 recorded events. The data records came with a list of attributes (See ***Table 25***)

*Table 25 - Data attributes provided in QC fire records*

| | | |
|---|---|---|
| • Administrative district (1-5)<br>• Event date<br>• Event time<br>• Time of fire out<br>• Address information | • Owner or Involved Party Details of Location of Fire Origin<br>• Fire Origin<br>• Type of Occupancy | • Deaths and Injuries<br>• No. of Houses Affected<br>• Level of Fire Alarm (e.g. Verification, Alarms 1-5, Task Force A-B, General)<br>• Costs of Direct Damage |

Due to data entry inconsistencies, gaps in information and incomplete records, a significant amount of data preparation, cleaning and geocoding was required prior to conducting the various GIS analyses.

In preparation for spatial analysis, data was cleaned and geocoded based on the reported event addresses using Google's geocoding tool. As approximately 30% of the incident addresses could not be geocoded automatically, visual inspection and manual geocoding was undertaken for the remaining data points using a combination of Google maps, Wego maps and OpenStreetMaps (n=2,052). It was observed that automated geocoding errors were a result of a combination of data entry errors, inconsistent street names with mapping services, or a lack of "official" addresses (common for IS areas). The final fire dataset geocoded with a success rate of 96%, which is above the established minimum successful geocoding rate required to maintain spatial accuracy (85%, e.g., Ratcliffe, 2004). The incident locations were then imported into ArcGIS and projected into PRS_1992_Philippines_Zone_III (the national projected coordinate system for the Philippines).

From this dataset, the IS fire data was extracted from the total number of structural and non-structural fire events and cross-checked against more detailed fire investigation reports (n=1580). Note: Because coding of fire incidents (i.e. data entry) in IS occupancies is not standard, fires located in IS areas were not consistently captured by BFP. As such, address information for each IS fire incident was geolocated manually and then identified as an IS occupancy based on relationship to land-use data (i.e. a shapefile of IS areas in Quezon City) using GIS techniques (i.e. select by location and using a buffer of 20m for an assumed geo-coding error). Fire incident mapping and geospatial analyses based on this point data were then performed.

For polygon-based or area based geospatial analyses (i.e. urban risk indexing, data correlation, regression) the incident data was then spatially joined to the 2012 QC administrative boundaries – congressional districts and barangays. Congressional districts represent national legislative divisions for determining representation in the lower house of Congress. Barangay (a native Filipino term for village) is the smallest spatial area for which all Census and fire incident information is reported. The land area and residential population of barangays in Quezon City vary from 0.013 $km^2$ to 26 $km^2$ and 0 to 186,469 people, respectively (2010 Census). Despite the large variation in barangay size, this unit of aggregate provides the most utility for urban planners and disaster managers, as this is the smallest level at which census data is collected and upon which administrative plans/decisions are made. Note: Since 2010, Quezon City is divided into 142 barangays and 6 congressional districts.

Note: As point data and polygon data geospatial analyses were performed, the impact of different levels of aggregation were evaluated explicitly. In addition, different levels of aggregation were also assessed as part of the hot spot analysis for point incident data (e.g. aggregating based on 0m, 20m, 50m, 100m radii). See Hot Spot Analysis for details.

Finally, fire hydrant location data provided by BFP in Excel format had significant data entry errors (i.e. incorrect lat/long coordinates, unclear address locations and/or missing hydrants). Thus, all fire hydrant locations (n=1,630) were visually inspected using a combination of Google Street View and the pdf map of hydrants managed by Maynilad Water Services Inc. – the main water concessionaire servicing western QC. The pdf map of Maynilad hydrants was georeferenced within ArcMap georeferencing toolbar. The final hydrant locations were imported into ArcGIS and projected into PRS_1992_Philippines_Zone_III.

#### *B.2.4.2 Descriptive Fire Statistics in ArcGIS*

First, basic descriptive fire statistics are explored by mapping fire incidents (by range of years, by years, by nature of fire) and fire impacts (by deaths, by injuries, by damaged homes, by economic losses). The statistics tool in ArcGIS is run to obtain total, min, max, mean, standard deviation, % of total, etc. Statistics for fire alarm level is also obtained using select by attribute at each level. (Fire alarm level is assumed as a proxy for fire severity, and firefighting resource demands)

To obtain fire statistics on IS fires, the fire incident point data is intersected with the land-use polygon shape file, and a 20m buffer diameter is assumed for geocoding error. General statistics are then obtained (total, min/max/mean/std by year, total by barangay). Distribution of fire alarm levels for IS fires is obtained using select by attribute (at each alarm level) and the select by location for IS areas. A frequency analysis is also undertaken to obtain frequency of all fire incidents and IS fire incident city-wide and by barangay.

#### *B.2.4.3 Simple Spatial and Temporal Analysis*

Second, spatial distribution of fire incidents is explored using density surfaces to identify high concentrations/clustering of fire events in a neighborhood. In addition to providing a map of fire frequency as a function of area (that can serve as a proxy for fire risk exposure), fire density surfaces can be overlaid with IS areas to assess percentage of fires geocoded in and/or near IS areas and provide a visualization of areas where fire incidents are problematic relative to others.

A reasonable neighborhood for urban contexts is assumed to be 1 $km^2$ (100ha). Initially, point density was used to evaluate fire density because all fire incidents within a neighborhood would be counted equally. However, kernel density estimation (KDE) (Silverman, 1986) – a spatial smoothing technique whereby a quadratic formula is used to assign the highest value at the center of the surface (the point location) and taper to zero at the search radius distance – was also used to assess the spatial variations of fire distribution. Also, KDE provides an indication of incident concentration across the study area, whilst not being constrained to an administrative boundary (or other geometric constraint).

In this context, however, where no weighted values were assigned for each fire event, there is a concern that the kernel density surface may not recognize coincident fire incidents (Gatrell, 1996; Silverman, 1986). Thus, both tools were used to highlight any significant anomalies. Fire incident density surfaces were performed for all fire incidents, structural fires, and IS fires.

While density surfaces provide some insight into spatial distribution of fire incidents, they do not indicate if the high clustering of fire incidents has statistical significance. Thus, the following section describes the methods used to assess geospatial statistical significance applied to fire incident and fire impact data.

The temporal patterns analysis explored fire incidents and fire causes broken down by hour-of-day and month-of-year, with data displayed using spider diagrams to accurately visualize the continuous nature of these temporal categories and for quick identification of times with more (or fewer) events than expected. (Note: The spider diagrams results are presented in the Fire Statistics section for better flow of content). In addition, fire density surfaces were also mapped for each year to observe any other temporal patterns.

#### *B.2.4.4 Geospatial Statistical Analysis*

To assess statistically significant spatial patterns of fire events ESRI's Hot Spot Analysis tool, found in the Spatial Statistics toolbox, was used. This tool calculates the Getis-Ord Gi* statistic for each area, outputting a Z-score which identified areas with statistically significant clustering of high values (i.e. $Z > 1.96$) and clustering of low values (i.e. $Z < -1.96$). In other words, the larger the z-score the more intense the clustering of high fire incident counts (hot spot), and conversely the smaller the z-score the more intense the clustering of low fire incident counts (cold spot). With a critical Z score value of -1.96 or +1.96 standard deviations, one has a 95% confidence level that the exhibited pattern is not due to randomness.

A primary goal of spatial analysis of event data is to aid in resource allocation and proactive planning (Asgary, A., Ghaffari, A., Levy, J. (2010); Corcoran, 2011). Identifying locations with high occurrence volumes is of operational interest. For this study, the hot spots can be compared with socio-economic indicators (such as IS areas) to see if there is a statistically significant correlation, to inform interventions. The output from the hot spot analysis tool was mapped at the city-level. Hot spot analysis was performed for all fire incidents, by fire alarm level (a proxy for fire severity), by ranges of time for fire alarm level, by a weighted alarm level, and for all fire impact metrics (e.g. deaths, injuries).

In general, the following steps were performed as part of the hot spot analysis:

- Use the Integrate tool to merge data points within a specified distance*
- Use the Count Events tool to collate, merged data points
- Use Incremental Spatial Autocorrelation tool to determine an appropriate bandwidth distance (i.e. the distance at which statistically significant clustering is first determined)
- Use Hot Spot Analysis tool
- Use Inverse Distance Weighted (IDW) tool to create hot spot surface

*The integrate tool is only necessary where the data points do not have assigned values, as is the case for fire incidents. Where statistically significant spatial autocorrelation was not observed, descriptive statistics were gathered instead

Note: For the fire alarm hot spot analyses, each alarm level was assigned a weight based on the required equipment resources needed for response. In geospatial analyses of point data information, each fire record is assigned a value of 1 by ArcGIS. However, when undertaking studies to assess significance of fire problems (e.g. hot spot analysis) one may want to assign weights to each fire count to reflect the severity of the fire event. As not all reported fire incidents are of the same severity, a weighting scale was applied to each fire incident based on the fire alarm level reported. Recall that fire alarm levels reflect the number of fire trucks and personnel called to the fire incident. The higher the alarm level the more trucks and personnel respond.

Typically, any alarm level beyond "verification" level means that there was an actual fire and not false alarm or other non-flaming fire. Three different weighting schemes were explored. The finally weighting scale (w3) was adopted, as it had the most physical meaning. This scheme assumed a linear relationship between the alarm level and the number of responding fire trucks, given that the verification level would be the baseline at a value of 0.5. See Table below for weights.

| Fire Alarm Level | Number of Responding Fire Truck | Weight w1 | Weight w2 | Weight w3 |
|---|---|---|---|---|
| Verification | 1 | 0.5 | 0 | 0.5 |
| 1st | 4 | 1 | 1 | 2 |
| 2nd | 8 | 2 | 2 | 4 |
| 3rd | 13 | 3 | 3.25 | 6.5 |
| 4th | 16 | 4 | 4 | 8 |
| 5th | 19 | 5 | 4.75 | 9.5 |
| TFA | 23 | 6 | 5.75 | 11.5 |
| TFB | 27 | 6 | 6.75 | 13.5 |
| TFC | 31 | 6 | 7.75 | 15.5 |
| TFD | 35 | 6 | 8.75 | 17.5 |
| TFE | 39 | 6 | 9.75 | 19.5 |
| General | ALL | 6 | 15 | 21 |

### *B.2.4.5 Fire Service Coverage Area Analysis*

The methodologies in the previous sections aim to evaluate risk from more traditional viewpoints – fire incidents (frequency or probability) and fire impacts (e.g. consequences). The analysis in this section aims to evaluate fire risk from a vulnerability perspective – specifically, firefighting capacities at the city level. While this analysis does not directly relate to the causes of fire ignition, it does correlate with the severity and impact of fires particularly in cities were population and structural densities are high (Granito, 2003; Jennings, 2013). Few fire risk assessment methodologies evaluate fire-fighting capacities alongside fire incident rates and impacts, when evaluating overall fire risks at the city level (Ferreira, 2016). In this study, the following firefighting features were assessed as a proxy for city-wide firefighting capacity:

- Number of Fire Fighting Personnel
- Number of Fire Trucks
- Fire Station Service Areas (response times)
- Fire hydrant spacing
- Fire hydrant water flow coverage

These firefighting features were assessed against internationally recognized standards (many of which have been adopted in the Philippines) using a variety of tools within ArcGIS. The methods and performance criteria are summarized in Table 26. The performance criteria for Items 1 & 2 are considered "good practice", while Items 3&4 are recommended guidelines that are more directly related to the influence of time and firefighter effectiveness in minimizing life and property losses. Item 5 is a minimum level of safety, as the effectiveness of water supplies degrades significantly due to pressure losses as hydrants become more remote from the fire. This analysis assesses various firefighting capacities against international standards, which society deems as the "minimum level of safety".

*Table 26 – Analytical Method and Performance Criteria Used to Assess Firefighting Capacity*

| Firefighting Feature | Analytical Method in GIS | Performance Criteria | Reference |
|---|---|---|---|
| 1. Firefighter personnel | Dissolve fire stations, associated personnel and barangay demographics (i.e. population) by 6 Main Fire Districts | 1 firefighter per 2000 people | NFPA 1710 and BFP |
| 2. Fire trucks | Aggregate number of fire trucks and barangay demographics (i.e. population) by 6 Main Fire Districts | 1 truck per 28,000 people | NFPA 1710 and BFP |
| 3. Fire Station Service Area | Response Time Analysis using ArcGIS online Generate Service Area tool | 4 min (travel time) | NFPA 1710 |
| 4. Fire hydrant spacing | Network analysis tool using hydrant locations and street shapefiles | 150m to 300m along roadway depending on occupancy | International Building/Fire Code |
| 5. Fire hydrant water flow coverage | Point buffer analysis | 50m | NFPA 1 and International Fire Code Appendix B |

For the personnel and fire truck assessment, data was provided based on which main fire station (and in some based sub-station) the resources belong to. As such, the data required a spatial join based on the barangay and station identifiers. Next, the barangay data with associated fire station details (personnel and equipment) was dissolved to the 6 fire districts, so that the respective firefighting feature could be evaluated based on the population served by each fire station. Results were tabulated for comparison to performance criteria.

As one of the primary responsibilities of a fire department is the timely delivery of fire and rescue services (Barr, 2003), a response time analysis has been performed. This is because time has a direct relationship with fire loss (i.e. the longer the response time the more critical and extensive the fire impacts). This can be better understood by the relationship time has to fire growth. Fire growth at the early stages can grow exponentially with time, to the point where complete flashover (i.e. all contents in the room of fire origin are ignited) can occur within the first 10 minutes of ignition (see **Error! Reference source not found.**). As fire department travel time is one of the more manageable features of the entire fire life cycle, having fire stations appropriately located with respect to time is critical (See Figure 72). This is assessed using response time studies.

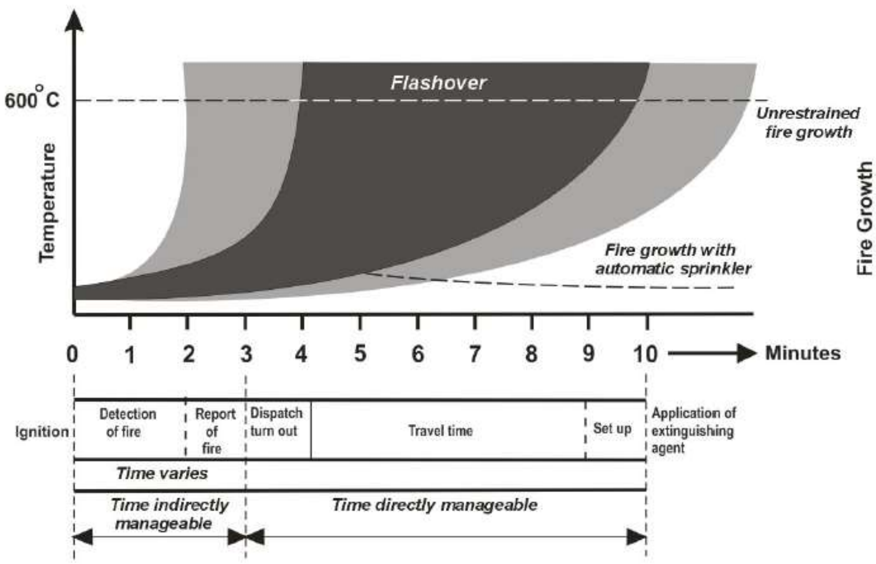



*Figure 71 - Fire growth as a function of time and relationship to key events in the fire life cycle from ignition to firefighter operations (ESRI, 2007).*

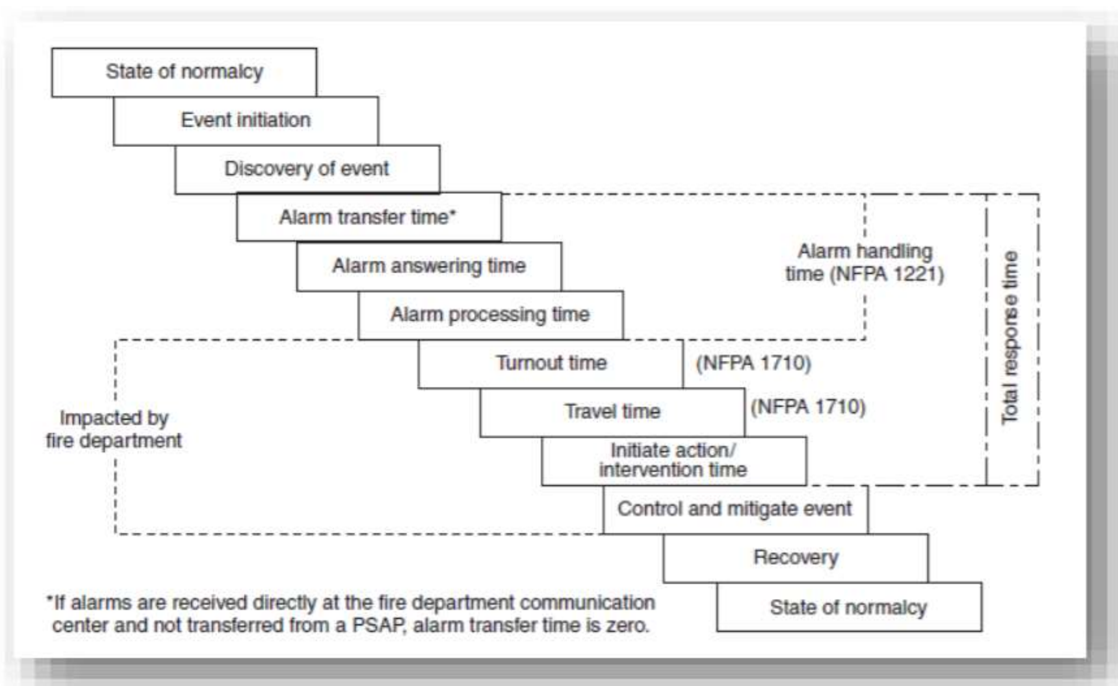



*Figure 72 – Cascade of events of fire cycle relative to fire-fighting operations (ESRI, 2007).*

For this analysis, a properly annotated street network database was not available for Quezon City/Metro Manila. Thus, the Response Time Analysis was performed using the ArcGIS online Generate Service Area tool. This tool creates a service area network analysis layer (a region that encompasses all streets that can be accessed within a given distance or travel time from one or more facilities), sets the analysis properties, and solves the analysis (ESRI, 2011). As Metro Manila is heavily congested and emergency vehicle lanes are not generally provided, emergency services can be severely delayed. Thus, the Response Time Analysis was performed for a representative low congestion period (e.g. Sunday at 2am) and a representative high congestion period (e.g. Friday at 5pm). For this study, a range of response times (4, 6, 8, 10 and 15 min) and associated travel distances were evaluated for both low and high traffic conditions. Response contour maps of fire station coverage have been produced to quickly ascertain the areas of the city that are underserved with respect to response times and therefore susceptible to more severe fire impacts. These maps were also overlaid with the IS areas to see where they maybe any correlations.

Closely linked with fire department response time, is the need for a safe, reliable and efficient supply of water. Controlling and extinguishing a severe fire are considered one of the most effective lifesaving actions a fire department can perform (Granito, 2003). In many communities, particularly large cities, water is supplied by hydrants. While there is no fixed standard on fire hydrant spacing, a general rule of thumb is to space hydrants every 150m (500ft) for closely built areas (Schultz, 2003). This was assessed using the Network Analysis tool, and the provided Quezon City street shapefile and hydrant location shapefile. The analysis assessed a travel distance of 150m and 300m.

In addition to spacing between hydrants, there is also no set standard for how close built environments should be to a hydrant or set of hydrants for sufficient waterflow. For this purpose of this report, NFPA 1 guidance was used to define a 50m point buffer as considered appropriate to roughly get at 1000gpm at approximately a total distance of 100m from a street hydrant to all sides of a structure (NFPA 1, 2018).

#### *B.2.4.6 Correlation of Socio-Economic Variables and Fire Incidents*

Finally, an exploratory analysis of fire "hot spots" in Annex B.2.4.4 is undertaken to assess correlations with socio-economic characteristics, since most fires are caused by some form of human presence or activity (NFPA, 2003; Jennings, 2013). New to this work is the inclusion of IS explanatory variables. The most common method for examining the existence of trends is simple linear regression, a parametric statistical technique that requires independent random samples drawn from normally distributed populations (Taylor and Taylor 1977).

Prior to conducting the analysis, a review of existing research on fire incidence (as well as fatal fire incidence) and socio-economic variables was performed. Jennings (2013) detailed a series of seminal research studies, primarily in developed nations, performed between 1970-2000 and well as more recent work (2000 to present). From ecological approaches, it was recognized that fire incidence and severity involved a "complex web of technical, organizational, economic and human dynamics as they interact against a context of built environment to produce fire losses (Jennings 2013, p. 15)." In these early studies and the numerous following, consistent relationships linked fire incidences to social and economic characteristics (e.g. poverty, household income, population, property tenure, education, unemployment, one parent families, percent population under 16 or over 65, ethnicity), physical environment such as housing and neighborhood conditions (e.g. housing conditions, overcrowding, vacant housing, housing type) and behavior traits (e.g. smoking, drinking, psychological beliefs/attitudes). (Jennings, 1999; Munson & Wallace, 1983; Fahy & Miller, 1989; Corcoran et al, 2007; Corcoran et al, 2011; Chettri et al; 2010).

Similarly, investigations were performed to explore and/or explain severe fire impacts and societal characteristics. In this case, fatal fire incidents were more strongly linked to characteristics of socio-economic depravity (e.g. population density, demographic characteristics, building types, smoking patterns, smoke detection, education) (Gunther, 1981; Holborn, Nolan, & Golt, 2003; Krisp, Virrantaus, & Jolma, 2005; Runyan, Bangdiwala, Linzer, Sacks, & Butts, 1992; Shai & Lupinacci, 2003).

Thus, the set of explanatory variables for fire incidence evaluated in this study is presented in ***Table 27***. This has been based on the literature review, fire engineering judgment, the availability of census data, and other key features in a developing city context (i.e. informal settlements, derelict housing)

*Table 27 - List of Explanatory Variables used in Fire Incident Occurrence*

| Variable Type | Independent Variables | Description |
|---|---|---|
| Presence of People | Population | Count of total people living in area |
| | Population Density | Count of people living in area divided by area (# of people/km2) |
| | Number of Households | Count of households (i.e. people living together with communal cooking, heating, etc.) |
| Urbanization | Number of Buildings | Count of buildings |
| Limited Fire Safety Awareness | Children below 9 years | Count of children below 9 years |
| | Elderly above 65 | Count of people more than 65 years |
| | Low Education | Count of people with no education over age 10 |
| Poverty | Poor Families | Count of families living in poverty |
| Poor Construction | Sub-standard buildings | Count of buildings constructed of poor standards |
| | Combustible construction | Count of buildings of combustible and/or lightweight construction |
| | Combustible roof | Count of buildings with combustible and/or lightweight construction |
| | Old Buildings | Count of buildings constructed before 1980 |
| | Unofficial structures | Count of informal settlement shacks |
| Crime Rate<br>(as a proxy for arson) | Crime rate | Count of crimes reported per 1000 people |
| High Fire Hazard Uses | Total hazardous buildings | Count of hazardous buildings |
| | Multi-unit Buildings | Count of multi-unit buildings |
| | Residential Buildings | % of buildings that are residential |
| | Informal Settlements | Area of Informal settlements |
| Proximity to Features | Distance to IS Areas | Distance to Large IS areas (m) |
| | Distance to High Hazard Areas | Distance to high hazard areas (m) |
| | Distance to CBD | Distance to commercial business districts (m) |

As census tract level has been observed to provide the most explanatory power, and has greater urban management utility, fire data and socio-economic variables are aggregated to the barangay level. Each parameter is evaluated for normality by generating histograms and for linear/non-linear relation in scatterplots. A hot spot analysis for fire incidents at barangay level is evaluated and compared against the point fire incident hot spot analysis in Annex B.2.4.4.

Note: While it is recognized that the general requirements for linear regression analysis may or may not be met in wall-to-wall geospatial data sets vs. a statistically drawn sample (Schlagel and Newton 1996), and a non-parametric statistical test is more appropriate, preparing the data for OLS and assessing the characteristics of the variable is worth testing. It is also not uncommon for data expressing abundance, such as fire distribution will differ significantly from the normal distribution and be skewed towards small values. Nonetheless, the intent is to explore OLS linear regression as the starting point of this study to help explain some of the long-term, macro-level fire patterns in QC. In the event a global model is successful, a GWR (graphically weighted regression) analysis will be performed to assess localized, non-stationary fire characteristics. The intent is to highlight parameters that are of significance to help direct more targeted interventions, and potentially use to monitor and/or predict current and future fire risk with the inclusion of IS variables.

### B.2.5 Urban Fire Risk Index

Complimenting the analyses in the previous sections on the IS fire problem, the approach presented in this section aims to provide decision makers with a composite urban fire risk indicator that is based on an integrated perspective of fire engineering, historical fire incident data, and interdisciplinary socio-economic vulnerability factors. The proposed approach for evaluating urban fire risk is based on the Urban Disaster Risk Index (URDI) theoretical and analytical methodology developed by Cardona et al (2001, 2005). The approach is based on a holistic and interdisciplinary view of disaster risk at the urban level, that not only considers the expected physical impacts (e.g. casualties, direct economic losses) from a hazard event, but also the second-order effects (indirect impacts) related to social vulnerability and coping capacity of the society. Using a multi-criteria approach, disaster risk (in this case fire risk) at the city level can be evaluated using indices and indicators (Cardona 2006). This constructive rationality provides the flexibility for incorporating and estimating the uncertain, incommensurable and multidimensional aspects/effects associated with understanding the complex nature of urban fire risk in a multiple variable environment (Munda 2000). Furthermore, as this approach has already been implemented in Quezon to assess seismic and flood risk (QCDRRMO, 2013/1, 2013/2, 2013/3), modifying the approach to include fire risk will provide decision makers with a more comprehensive view of the overall risk environment for the city.

The governing equation for the URDI method is defined as follows:

$$URDI = \sum_{i=1}^{n} R_{F_i} \times (1 + F_i) \qquad \textit{(Equation 1)}$$

Where, $R_F$ is the physical risk index for each hazard (e.g. seismic, flood, landslide, fire) and unit of analysis (i). For this study, the unit of analysis is the barangay level – the lowest administrative level in the Philippines. $R_F$ is determined by the weighted ($w_j$,) sum of all physical risk indicators ($R_{F_i}$,) such as casualties, direct financial damages, etc. for each hazard as follows:

$$\boldsymbol{R_{F_i} = \sum_{j=1}^{n} R_{F_j} \times w_j}$$

$F_i$, in Equation 1, is the aggravating coefficient for the unit of analysis (i), and is comprised of the weighted ($w_{f_k}$, $w_{f_l}$) sum of the social vulnerabilities indicators ($F_{f_k}$,) and coping capacity ($F_{f_l}$,) of the community, as given by:

$$\boldsymbol{F_i = \sum_{k=1}^{n} F_{f_k} \times w_{f_k} + \sum_{k=1}^{n} F_{f_l} \times w_{f_l}}$$

The process of developing the UDRI consists of five main steps (See Figure 73).

**Step 1: Theoretical Concept**

- Identify and define the various dimensions (physical, social, economic, environmental, political, etc.) and subsystems of the built environment and society, and the fragility and resilience factors identified for each subsystem

**Step 2: Indicator Selection**

- Identify and define indicators for each sub-system
- Collect requisite data
- Indicators should be reliable, accessible, reproducible, interpretable, and accurate

**Step 3: Normalization**

- Normalize indicators and sub-indicators on a scale from 0 to 1

**Step 4: Aggregation**

- Define weights for each indicator and sub-indicators
- Combine weighted indicators to obtain a single index value, UDRI
- Compile results to facilitate decision-making

**Step 5: Sensitivity Analysis**

- Perform sensitivity analyses to address different sources of uncertainty (e.g. weighting process, implementation of transformations functions, immeasurable dimensions, data collection errors)
- Test robustness of theoretical concept/framework

*Figure 73 - Theoretical framework of Urban Disaster Risk Index Method*

***Step 1 – Theoretical Concept***

The first step in the process is to develop the overall structure of the URDI given the local context – identifying the physical risk indices (e.g. seismic, flood, fire) and their associated impact indicators (e.g. population loss, building loss), as well as, identifying the indirect impact factors for the socio-economic impact index, all relevant sub-systems (e.g. social vulnerability index) and associated indicators. Figure 74 illustrates the main structure of the URDI previously assessed for Quezon City, but with the inclusion of a fire index (the subject of this thesis). Note: The remaining sections will focus on the proposed features of the fire risk index. Refer the literature (QCDRRMO, 2013/1) for additional details regarding the seismic and floor risk indices determinations.

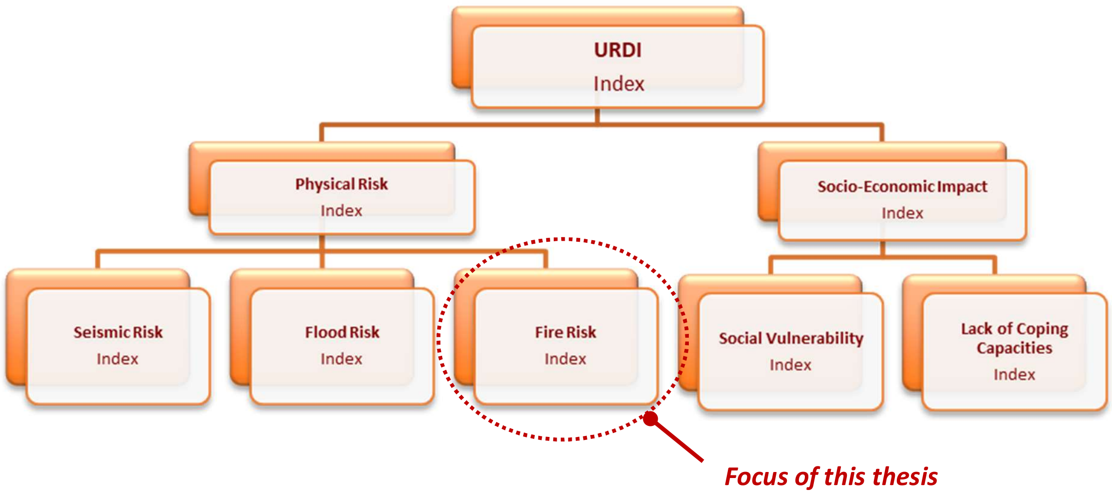



*Figure 74 - Structure of URDI for Quezon City with addition of the Fire Risk Index*

***Step 2 – Indicator Selection***

*Physical Risk Indicators (R)* – The physical fire risk indicators for this study are derived from the fire incident data obtained from the BFP for Quezon City. Similar to the flood and seismic physical risk indicators in the previous study by EMI/QCG, the physical risk indicators for fire are provided in terms of two loss sectors: population and buildings. Within the population index, two sub-indicators are assessed: deaths and injuries. For the buildings impact index, two sub-indicators are provided: direct economic losses and affected housing. The physical impact indicators are common in fire loss analyses in industry. See Figure 75

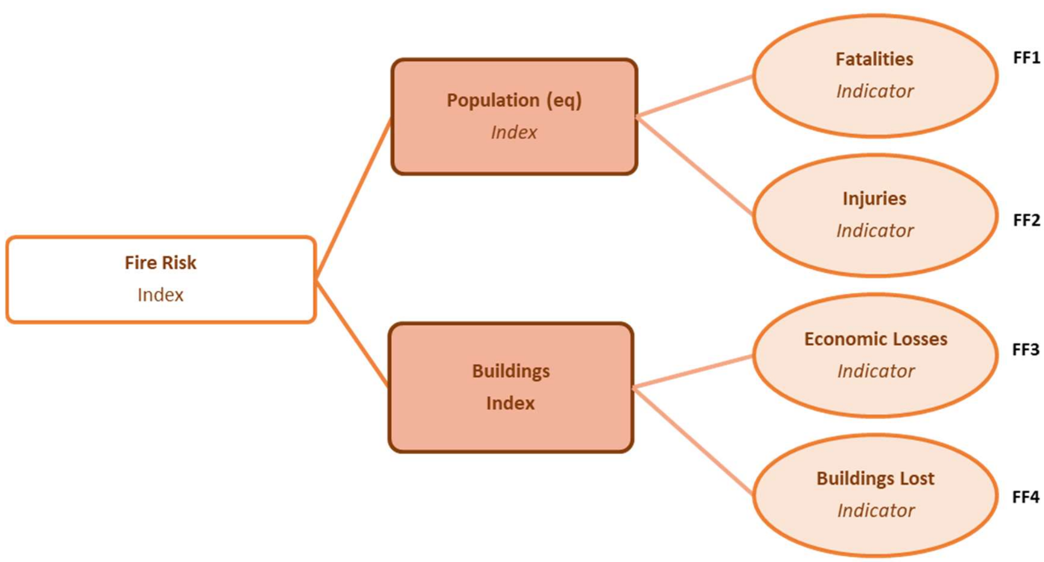



*Figure 75 – Fire Risk Indicators (ovals) and risk/loss categories (boxes)*

*Aggravating Coefficient or Socio-Economic Impact Factor (F)* – The socio-economic impact indicators for this study have been primarily taken from the previous study conducted by EMI in the Quezon

City Hazard, Vulnerability and Risk Assessment Report (QC HVRA) dated 2013. However, proposed modifications have been made to the firefighting capacity indicator as part of this thesis. The two main socio-economic impact factors are provided in term of two sectors: Social vulnerability index and Lack of Coping Capacities. The sub-indicators for social vulnerability can be seen in Figure 76 and are consistent with the EMI study. For the Lack of Coping Capacities Index, the sub indicators are Lack of Mitigation and Prevention, Lack of Hospital Capacity, and Lack of Firefighting Services. The first two indicators are consistent with the previous EMI study. However, for the Lack of Fire Fighting Services, this thesis proposed four sub-indicators based on four features: Response Time, Hydrant Coverage, Staff Ratio and Fire Trucks. The proposed fire indicators have been selected as proxies of firefighting capacities in the city and are based on fire engineering concepts and industry standards as discussed previously in Section B.2.4.5 and in the introduction. Each represent aspects required for effective firefighting operations (i.e. personnel, equipment, water and response time). While there are other indicators that can be used as proxies for a municipality's firefighting capacities (e.g. fire prevention spending, training hours, administrative staff) these are some of the most readily available and commonly used. (Brien, 2016; NFPA, 2003; ESRI, 2009; ESRI, 2007).

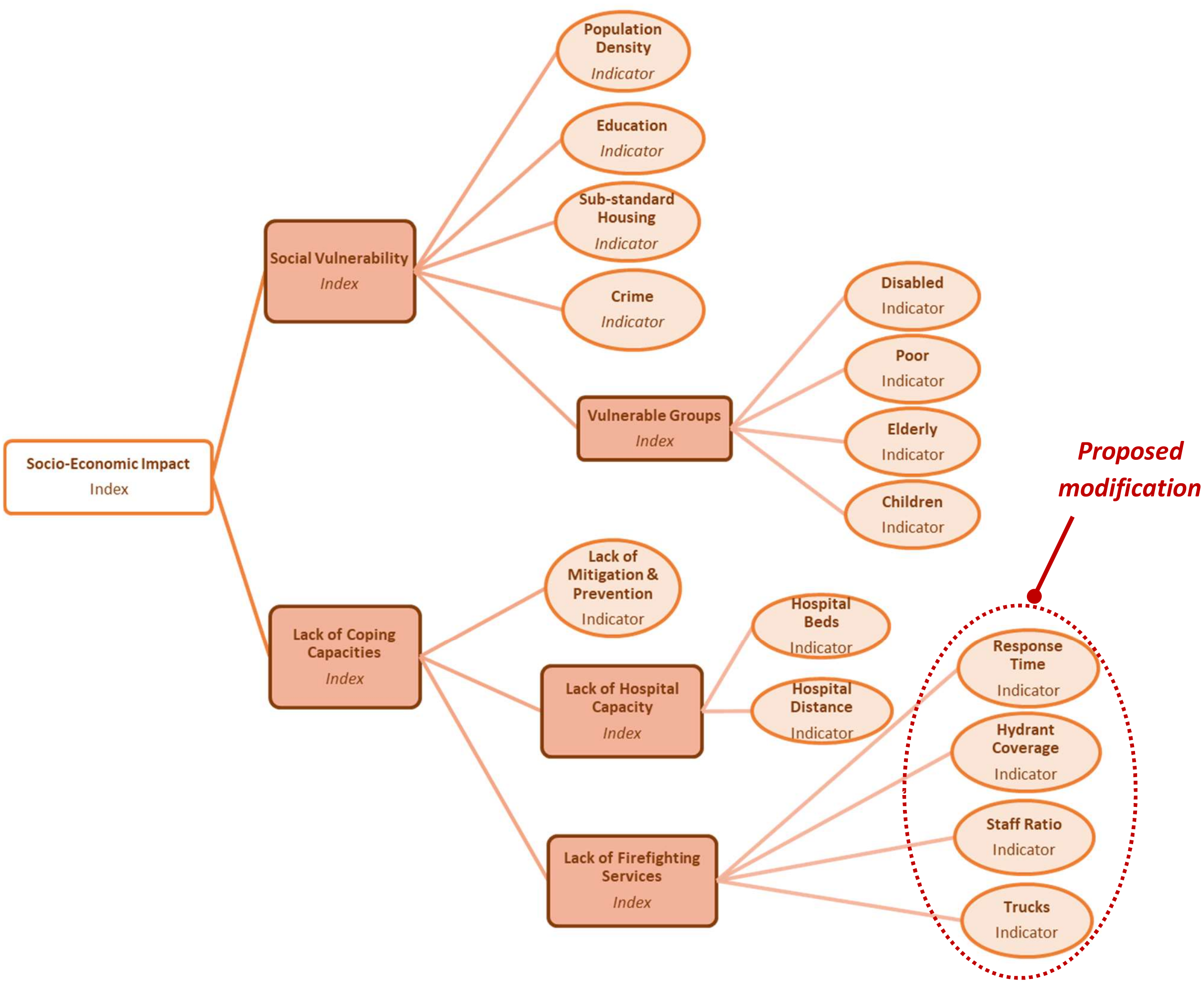



*Figure 76 – Social Vulnerability and Coping Capacity Indicators (ovals) and categories and sub-categories of the socio-economic impact factor (boxes). The Lack of Firefighting Services index has been modified as part of this study.*

***Step 3 – Normalization***

As the units for the various indicators are of incompatible or differing units, transformation functions have been used to normalize the data into values ranging from 0 to 1, as needed. The transformed values represent the intensity of the risk, whereby a value of 0 represents low risk and a value of 1 represents high risk/vulnerability. To be consistent with the EMI report, sigmoid functions were used for most of the indicators, except for the coping capacity indicators where linear transformations were used. Note: Indicators that are already a percentage or ratio have not been transformed further as they are already on a scale of 0 to 1.

For the proposed staffing and vehicles indicators, a transformation to normalize was not used as the indicator is already in terms of a ratio against the standard criteria as discussed in Section B.2.4.5. The hydrant coverage area indicator was based on the ratio of area covered by a 50m radius around all known hydrants and the area not covered within a barangay. This provided value that were from 0 to 1, and therefore transformation/normalization was not needed. While this indicator assumes that any area outside of 50m of a hydrant is "not safe", it is a relative risk comparison for hydrant coverage against an assumed international standard for quality of available firefighting water supplies. Note: This indicator assumed that all areas in QC have structures/buildings/uses that require fire hydrant coverage and/or require the general rule of 50m to a hydrant to achieve sufficient waterflow (e.g. hydrant operational status, higher waterflow requirement due to high fire hazard, etc).

For the response time indicator, all areas within 6 min of a fire station are assumed to be within a reasonable time for firefighting interventions to commence and within the timeframe when firefighting is the most effective in limiting property and life loss. See Section B.2.5.4 and Figure 71. This means that areas within 6 min are assumed to have no additional risk regarding response time capacity (i.e. value of 1). For all areas outside this 6 min range, a linear transformation was used to normalize the remaining areas relative to each other (resulting in values from 0.01 to 1, where the maximum response time was calculated to be 16.39 min, the minimum is 2 min, and the average is 5.09min). Recall: The response times were based on high congestion periods, as this the most severe and the most common condition in Metro Manila.

It should be noted that for all indexing methods, the process of normalizing data is somewhat subjective and can influence the overall results. This provides one source of error that should be tested in a sensitivity study, and also evaluated for appropriateness using engineering/expert judgment. The reasonableness of this normalization can also be evaluated by local operational leaders, as well as, compared against historical fire incident impacts. Another option is to undertake a regression analysis (as was intended in this study) to assess relative importance of each coping capacity against fire severity/impact data.

***Step 4 – Aggregation***

In the fourth step, the overall risk value is calculated, by aggregating the values of the weighted single sub-indicators. The assignment of weights for individual indicators has been taken from the previous EMI study. In the EMI study, weight factors were determined from a survey and focus group discussion with key emergency staff and disaster risk managers in Quezon City (QCDRRMO, 2013/2). For the proposed firefighting resources indicators, weights were assumed to be equal for all four fire-fighting features. Future studies (e.g. focus groups with fire operations staff and other experts, or regression analysis) could be performed to identify weights. Refer to Appendix for summary of final weight factors. Given the weight factors, the fire index is calculated based on Equation 1.

***Step 5 – Sensitivity Analysis***

The final step is to perform a sensitivity analysis of the various indicators according to the input data, their associated weights, and transformation functions. Once the important weights are evaluated, the analysis identifies any subset of factors that result in the output variance, as well as, the non-important factors. The shape of transformation functions and their effect on the total output variance was investigated.

***Note: For this study, only the urban fire risk index was determined. The total URDI including the seismic and flooding indices were not combined the fire index, as the values for the other two indices were not available.***

Refer to Annex D for more details of the assumed weights, the final data maps and sensitivity study.

## B.3 KEY ASSUMPTIONS

As with any analysis, several key assumptions have been made and are as follows:

| Key Assumptions |
| --- |
| 1. The fire incident data provided by QCBFP is assumed to satisfy industry standards for quality and accuracy |
| 2. The GIS data provided by QCDRRMO (QC administrative layers, DEM tiles, land-use, population data, emergency service locations, built environment data, hazardous facilities data, hydrology data, street data, etc) is assumed to be reasonably accurate and quality, meeting industry standards |
| 3. Projected coordinate system = 1992_Philippines_III<br>4. Reference system = WGS 1984 |
| 5. Refer to project file metadata for details of file restrictions/limitations |
| 6. Exchange rate from PHP to USD (50:1). |
| 7. The unknown or "under investigation" fire incidents are assumed to align with the proportions of the known incident characteristics. |
| 8. The data and indicator weights used in the previous EMI & QCG Urban Disaster Risk study are assumed to be reasonable accurate and of industry quality |
| 9. A 20 m geocoding error has been assumed when located fire incidents in IS areas. |
| 10. A "neighborhood" for determining the point density and kernel density analyses was assumed to be 1km$^2$ (100ha). |
| 11. The economic losses reported in this study are considered direct losses, and do not include indirect losses (e.g. lost wages). |
| 12. Deaths and injuries were based on immediate casualties directly caused by the fire incident. That is, no secondary life safety issues are assumed to contribute to the number of fatalities (i.e. deaths due to water borne diseases, delayed deaths or other crises post the initial event). |

## B.4 RESEARCH QUALITY

### B.4.1 Reliability and validity

The analysis undertaken in this study has been based primarily on data provided by QC officials at various levels of administration, as well as, extensive literature review process of academic, organizational, and industry publications. Although not presented in the report, the research basis and findings were also based on interviews with key officials at the QC DRRMO, the QC BFP, two local Barangay council members (Botocan and Batasan Hills), 1 local Barangay volunteer fire fighter (Batasan Hills) and 6 IS residents in two separate Barangays (Botocan and Batasan Hills). These multiple data sources were used to triangulate and cross-validate the input data and served as an internal quality check for the research.

### B.4.2 Limitations

This report and all its findings relate primarily to the local conditions in QC and the time frame in which the study was undertaken (September 2017 to August 2018). While the author was able to make two field visits between September 2017 – January 2018 and March 1-22, 2018 (for a total of 6 months), understanding local contexts and collecting data exceeded anticipated time frames. As local culture and practices primarily operate in "in-person" networking, data collection and ultimately the analysis performed was primarily limited to what could be collected during the two site visits.

In addition, much of the data provided by the QC government were limited to studies completed in 2009-2012, and therefore were not up-to-date with the fire incident data collected between 2010-2017. The informal settlement data available to QCG had not been updated since 2010. In a cursory review of satellite imagery, it was observed that numerous new IS areas have appeared particularly in the peripheral areas and/or places farther from the main commercial business districts (CBD). In this same vein, some IS areas have also been cleared through resettlement programs (e.g. Vertis North), which are also not reflected in the IS shape file used in the study.

The values, objectives and key assumptions presented herein are an integral part of the risk analysis and therefore the results and conclusions are not necessarily applicable to any other project/location without further assessment. The author also acknowledges that personal experiences and unconscious biases may have influenced research findings. As this research project attempted to evaluate urban informal settlement fire risks from multiple perspectives, the analysis and findings are still limited to one author evaluation. That is, this report/analysis should not be viewed in isolation but as part of a more holistic assessment satisfying the various performance objectives by all Stakeholders relevant to the current and future sustainable development goals of QC.

### B.4.3 Uncertainty

As with any research project, there is always some level of uncertainty to various aspects of the study. Below is list of these uncertainties.

- **Sample-size based uncertainty**
- **Sample-bias-based uncertainty** – For smaller more under-resourced stations and/or barangays fire incident data is likely under-represented or not in proportion to the population being served. Similarly, richer neighborhoods may report and track all incidents, as opposed to, just the major incidents or select victim groups
- **Missing data** – There is an 8% of incidents that have unknown or blank data. This can be resolved by assuming that these data match the proportion to the known data.
- **Coding inconsistences**
- **Error in determining facts of the cases**
    - Unmeasurable in absence of some indicator within incident report
    - Access to a more reliably accurate source of incident data

    - Consistent and reliable training of staff tasked with recording and inspecting incident data
- **Other uncertainties**
    - Standardized coding is not detailed enough
    - Non-specialists collecting data
    - Specific equipment, part of equipment, brand involved not recorded
    - Inconsistent interpretation of terms and categories
    - Data half-truths and myths
        - Data only reflects information collected/reported directly to the BFP. It excludes information shared/collected by the volunteer/private fire brigades.
        - What is objective of data collection by BFP? For funding? Justification of work? Need to show good results? So underreporting? Biased

Understanding past risk is not the same thing as understanding current risk nor projecting future risk however, and major challenges must be overcome to produce credible estimates. Three of the more difficult factors to predict are:

(1) changes in underlying socio-economic, political, legal environment influencing levels of poverty and expansion/contraction of informal settlement size, conditions, resident fire safety practices, etc.
(2) changes in population and development patterns that could expose more lives and property to fire effects
(3) the feedback effects of fires in one year on fire occurrence and behavior in following years.

Add to this backdrop of uncertainty, the additional questions about future climate and its impact on urban fire risk (e.g. increasing temperatures resulting in overburden/overheating electrical grid).

# ANNEX C. Field Survey of Two Informal Settlements in Quezon City

During two separate in-country visits, a field survey of over 100 buildings in two separate informal settlements in Quezon City was performed. The data collected in this survey was conducted using a web-based forms and GIS data collection tool (GIS Cloud). The survey data forms were prepared in advance of the trips and included options for taking pictures and geolocations of each building.

A desciptive analysis is presented below of some of the details collected.

## C.1 Construction

As part of a in-country field visit, a housing survey was undertaken for approximately 100 IS structures primarily in one large IS area in Barangay Batasan Hills and one in Barangay Botocan. In this survey, the majority of IS structures were constructured of unreinforced concrete/masonry blocks for the primary walls, with galvanized sheet metal and light timber framing for the roof (64%), which is also consitent with official census statistics for all buidlings in the city (See Figure 77).

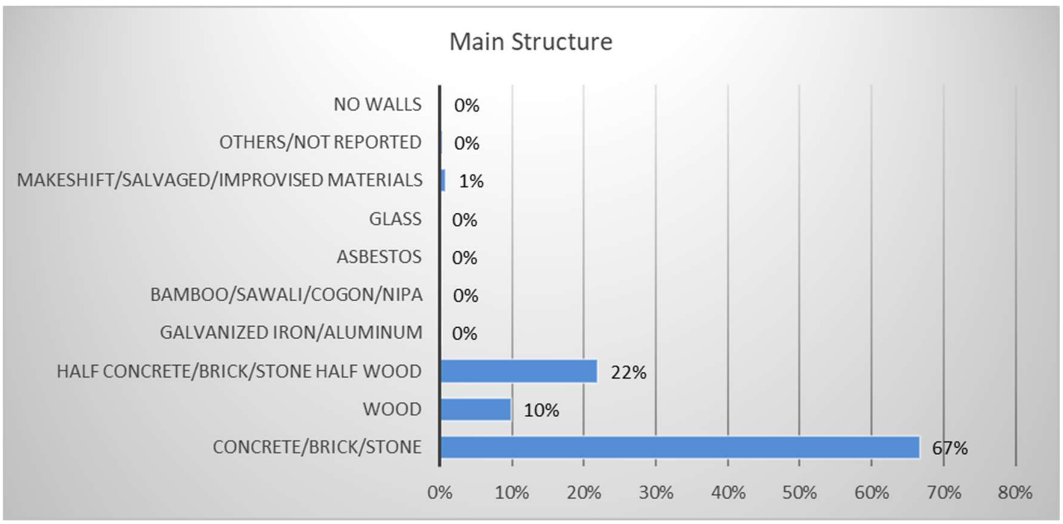



Figure 77 – Construction materials of main structures in Quezon City based on Census data (PSA)

That said, approximately 16% of the IS buildings in the survey were comprised of varying degrees of makeshift or salvaged materials (e.g. wood pallets, wood panels, plastic panels, steel bars, other light weight combustible materials, concrete blocks, sheet metal). See Figure 78. Due to the heteogenity of economic status in informal settlements, the quality of construction varied depending on the economic status of the residents. Very well constructed structures can be directly next to poorly constructied buildings. Also, the poorly constructed buildings have varying degrees of structural stability and integrity (e.g. gaps in between and within structural/non-structural components).


*Figure 78 – Sample images of typical building construction and use collected during survey of in informal settlements in Barangay Batasan Hills.*

In general, single IS dwelling units ranged in area from 10 to 30 $m^2$ and 3m in height. A plan view of a representative single family dwelling in illustrated in Figure 79. Due to the hot and humid climate, most structures had little to no insulation with a varying number of windows/openings for ventilation. In most cases, dwellings had a single door to the exterior, with door openings in the interior when multiple family units resided within.

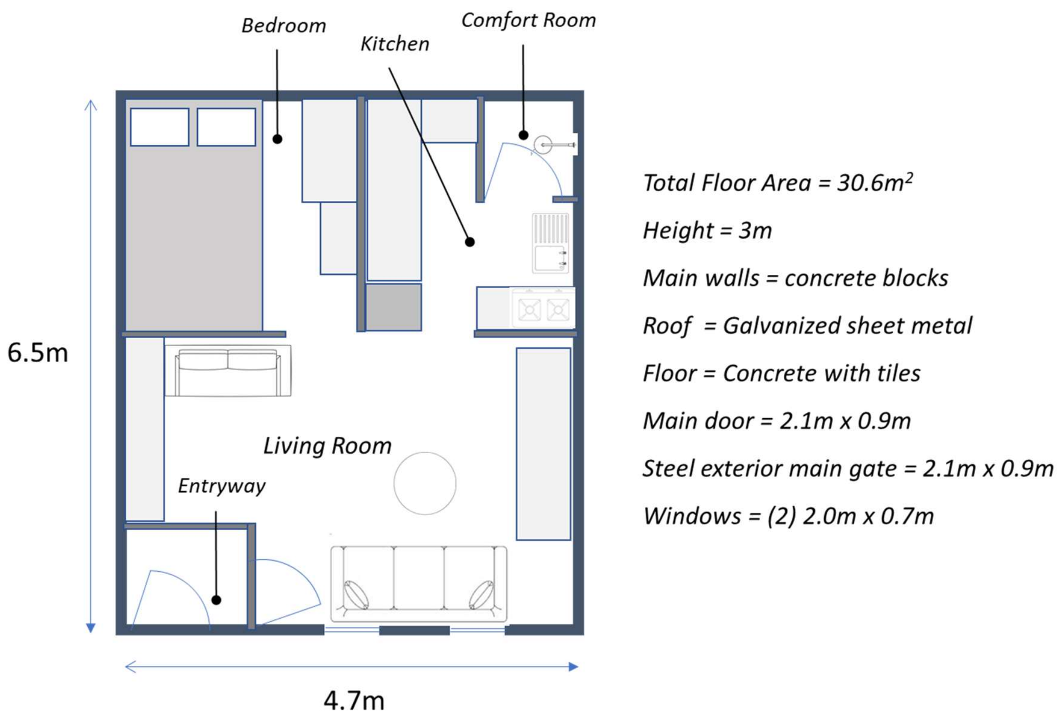



*Figure 79 - Schematic drawing of a represenative, informal settlement dwelling with typical dimensions and construction characteristics.*

## C.2 Occupant use

As informal settlements tend to be mini-cities wihtin the larger urban fabric, a large range of uses were present within the communities and wihtin individual buildings. ***Table 28*** shows the occupant uses observed as part of the survey. The majority of the buidlings were of a mixed-use residential, retail or residential and some other use. Many families utilized their strucures for both work and residential uses, which creates a range of combustible fuel loads of varying and unknown degrees, as well as, inconsitent occupant awareness characterisitcs (i.e. how familar occupants are of their surroundings).

*Table 28 - Occupant uses of Surveyed IS buildings*

| Occupant Use | % of Buildings Surveyed |
|---|---|
| Commercial/Office | 0.9 |
| Institutional/Government | 2.6 |
| Medical | 1.7 |
| Residential | 44.4 |
| Mixed-Use (Residential, Assembly, Retail) | 50.4 |

Furthermore, due to the large variation in fire loading from area to area, which can be function of materials that are readily available, income levels, building use, hoarding practices, an estimate on the fuel load density was not conducted. This would be subject of future research work.

## C.3 Access and Egress

In the area surveyed, buildings/structures were clustered together in irregular patterns with narrow passages ranging from 0.5 – 2 meters for access and egress between the clusters. In most cases, the buildings within a cluster are built immediately abutting the neighboring structures. Unlike informal settlements on the outskirts of the metropolitan area, the informal settlments located within the city center are very densely spaced. According to the World Bank report (Singh, 2017), Batasan Hills is considered a low density IS area (approximately 48,800 people/km$^2$, nearly 2x the average population density of the entire barangay). Botocan, on the other hand, is considered extremely high density at 201,612people/km$^2$. Where there are open areas or yards, the spaces are often used for storage of materials and/or rubbish. While waste collection is provided for many informal settlements in the surveyed areas, indivudal behavior can still result in significant areas of dumping and trash accumulation. See *Figure 80* showing images of the narrow access/egress paths within a typical informal settlement in Batasan Hills.

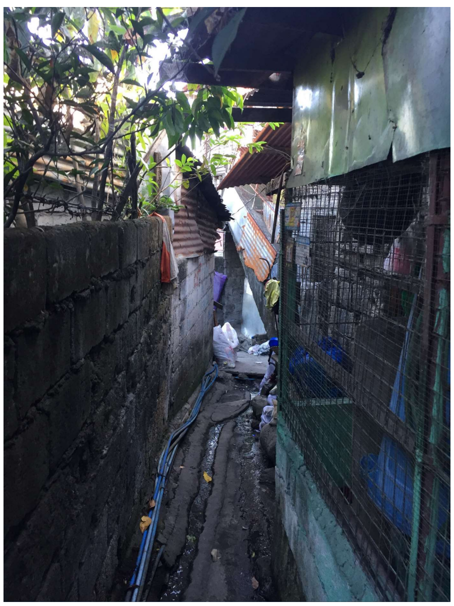
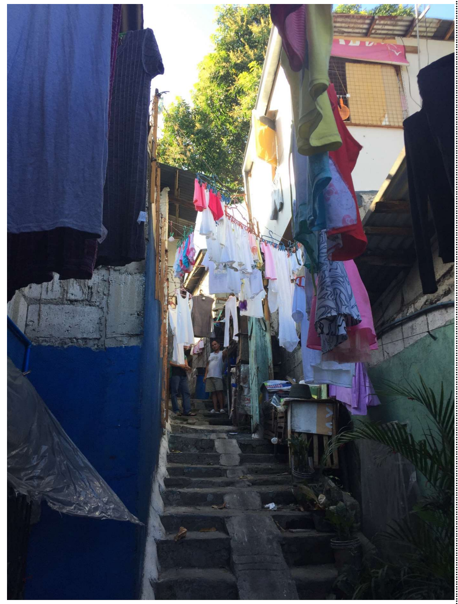


*Figure 80 – Sample images of narrow alleys (0.5 to 2m wide) in between clusters of dwellings in informal settlements in Barangay Batasan Hills.*



## C.4 Sources of Ignition

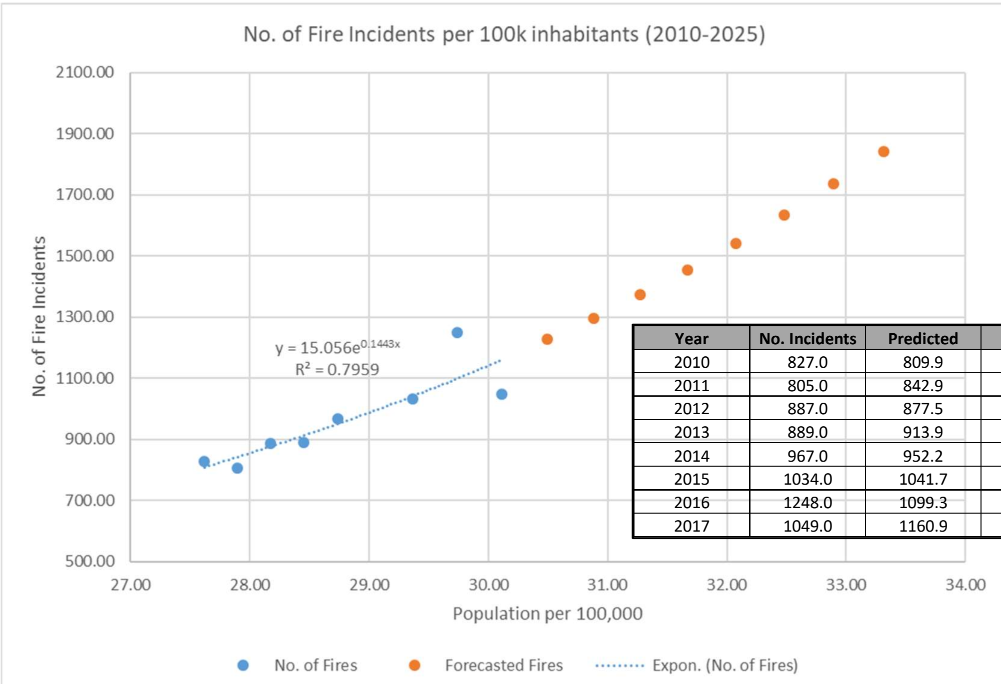
Based on visual observations and interviews with local residents, the QCDRRMO Director, and Barangay captains from Batasan Hills and Botocan, there are a number of potential ignition sources in informal settlements in Quezon City, such as: electrical faults (especially from illegal connections a.k.a. ”jumpers” or faulty applicances), overloaded electrical connections, open flames for cooking, LPG stoves, smoking, etc. The main concern highlighted for informal settlements, however, is the illegal electrical connections or ”jumpers”. See Figure 81.

*Figure 81 - Typical electrical post wiring nest in informal settlement areas. Illegal connections (aka "jumpers") are a common occurrence and source of ignition in Quezon City.*

# ANNEX D. Results Supplemental Data

## D.1 Fire Statistics – Simple Regression Model

In a simple regression model of fires incidents vs population (Figure 82), an exponential trendline achieves a fitness ratio ($R^2$) of approximately 0.796 with a reasonable distribution of residuals. This means that nearly 80% of the fire incidents in QC can be predicted purely based on the population model in the figure. Given this model, by 2025 the anticipated number of fire incidents could be as much as 1,842 annually (assuming population trends continue exponentially).



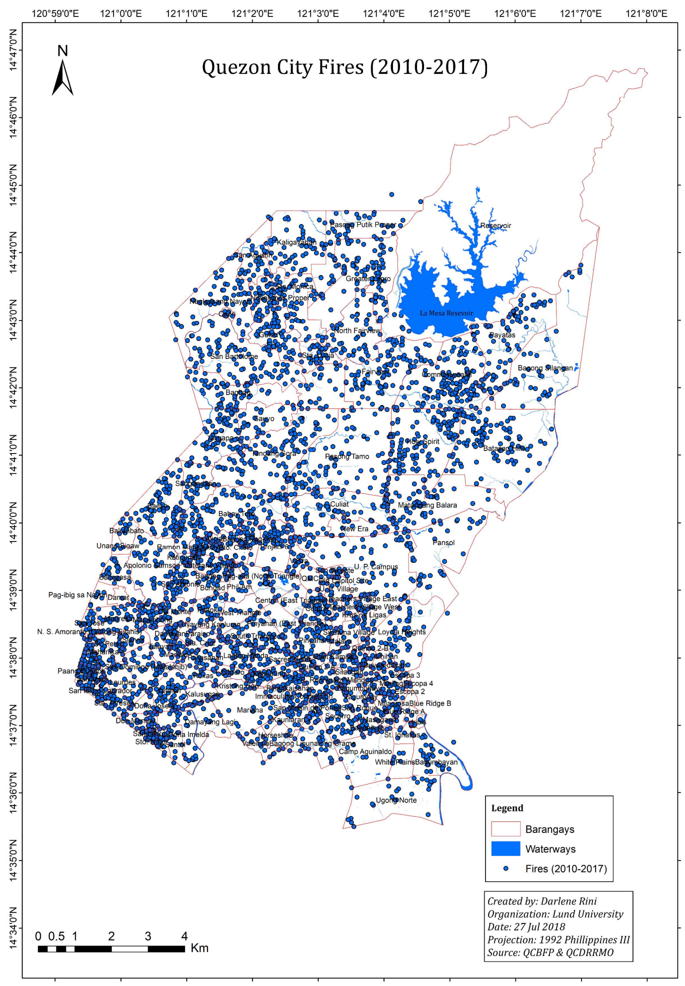

| Year | No. Incidents | Predicted | Residuals |
|---|---|---|---|
| 2010 | 827.0 | 809.9 | 17.1 |
| 2011 | 805.0 | 842.9 | -37.9 |
| 2012 | 887.0 | 877.5 | 9.5 |
| 2013 | 889.0 | 913.9 | -24.9 |
| 2014 | 967.0 | 952.2 | 14.8 |
| 2015 | 1034.0 | 1041.7 | -7.7 |
| 2016 | 1248.0 | 1099.3 | 148.7 |
| 2017 | 1049.0 | 1160.9 | -111.9 |

*Figure 82 - Simple regression analysis of fire incidents as a function of population from 2010-2017, predicting to 2025.*

## D.2 Geospatial Analysis – Mapping of Fire Incidents

As indicated in the main body, additional data inconsistencies were observed between the PSA data assessed in the statistical analysis and the BFP fire incident data used for the geospatial analysis. While the fire records from the PSA indicate a total count of 7,706 fires, the fire incident database from BFP had 991 records missing from 2015, along with other inconsistencies between the two record sets (see *Figure 83* table). Therefore, a total of 6,841 records have been evaluated in this part of the study.

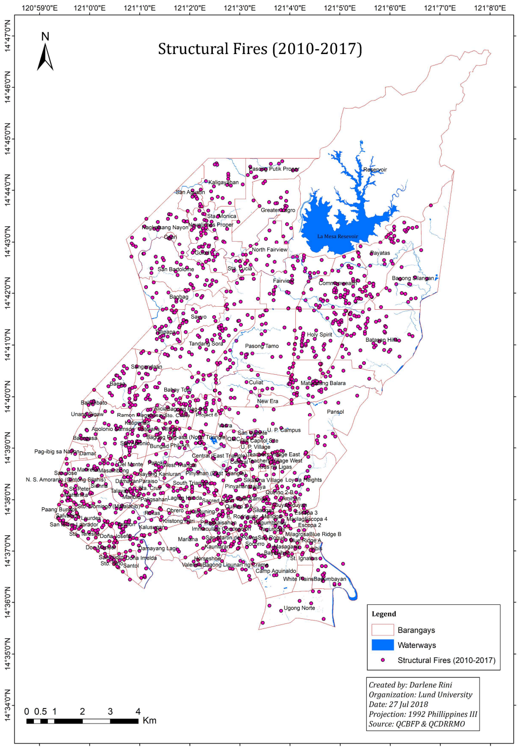
Between 2010-2017, a total of 6,841 fire incidents were recorded in the BFP fire database. All these records were geocoded and mapped based on typology for visual clarity (See *Figure 83* & Figure 84).

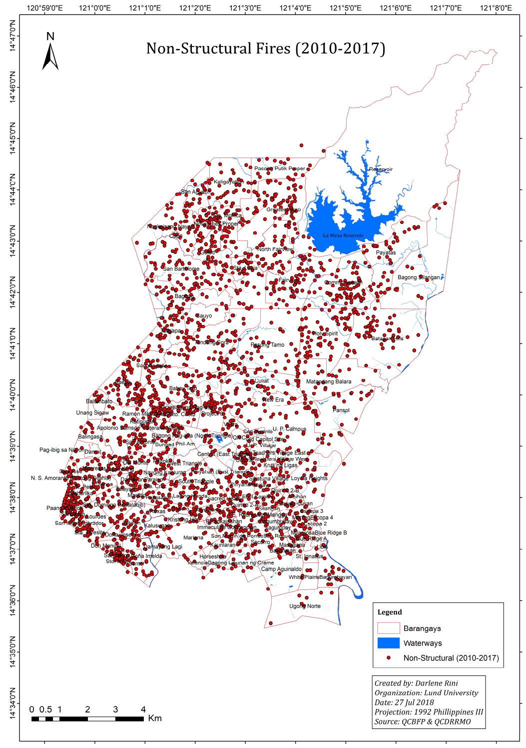


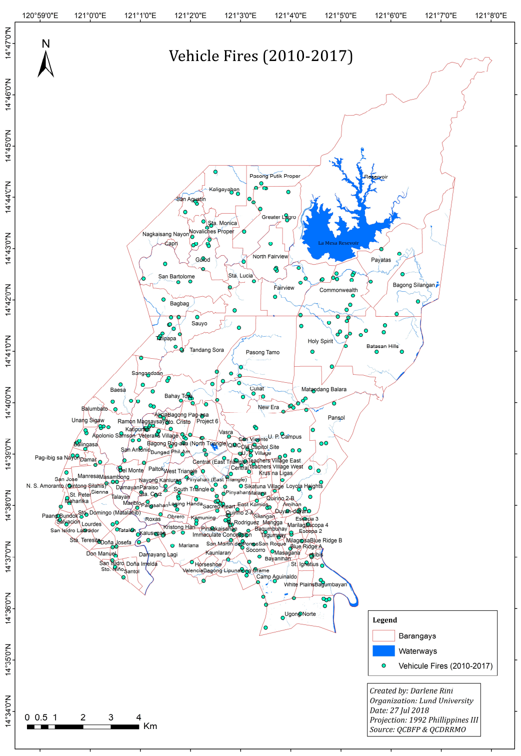

| Year | No of Fire Incident Reports (QC BFP records) | No. of Fire Incidents (PSA records) |
|---|---|---|
| 2010 | 826 | 827 |
| 2011 | 804 | 805 |
| 2012 | 887 | 887 |
| 2013 | 796 | 889 |
| 2014 | 967 | 967 |
| 2015 | 43* | 1034 |
| 2016 | 1132 | 1248 |
| 2017 | 1026 | 1049 |
| TOTAL | 6,481 | 7,706 |

**Complete records in QC BFP database were missing, and therefore not included*

*Figure 83 – All recorded fire incidents in Quezon City between 2010-2017 (n=6,841)*




| Fire Type | Description | No. of Incidents | % of Incidents | No. in IS Areas | % IS by Fire Type |
|---|---|---|---|---|---|
| Structural | Buildings | 1,832 | 28% | 567 | 31% |
| Non-Structural | Rubbish, Vegetation, Post, Gas, Others | 4,289 | 58% | 817 | 22% |
| Vehicular | Car, Ship, Airplane | 471 | 6% | 61 | 15% |
| Not-Coded | | 513 | 8% | 135 | 26% |
| Total | | *6,841* | | *1,580* | *23%* |

*Figure 84 – Map of all recorded fire incidents by typology. (Top Left) Structural Fires. (Top Right) Non-structural fires and (Bottom Left) Vehicular fires. (Bottom Right) Breakdown of fire incidents by type, description and % of total fire events*

From visual inspection, there appears to be some clustering of fire incidents in various pockets around the city primarily with the non-vehicle fire incidents. That said, vehicle fires typically follow road ways and thus will have more linear clustering compared to other fire typologies.

## D.3 Geospatial Analysis – Hot spot response time analysis

Since response time analysis in ArcGIS may not capture all "in life" conditions, a hot spot analysis of historical response times between 2010-2017 has been undertaken and presented in ***Figure 85***. Areas with statistically significant response times are shown in dark red, while areas with statistically significant low response times are shown in dark blue. As seen, the northern/northeastern parts of the city have long response time "hot spots", while the central and southern parts having lower response times. While the GIS predictive response time map differs from the historical times, there are consistently high response time areas in both (i.e. Pasong Tamo, Tandang Sora, Pasong Putik Proper).

While looking at the average response time of ~4.5min city-wide may seem reasonable, upon closer inspection, there are several cases where the times are significantly longer (i.e. 24% of all calls > 6 min; one call took 56 min). For IS areas, 21% of the response calls are more than 6 min. These increased travel times have a direct impact on human and property fire losses and are likely a combination of being understaffed/unsourced but also constrained by the traffic congestion in the city. Nonetheless, this is a critical deficiency to fire safety for the city.

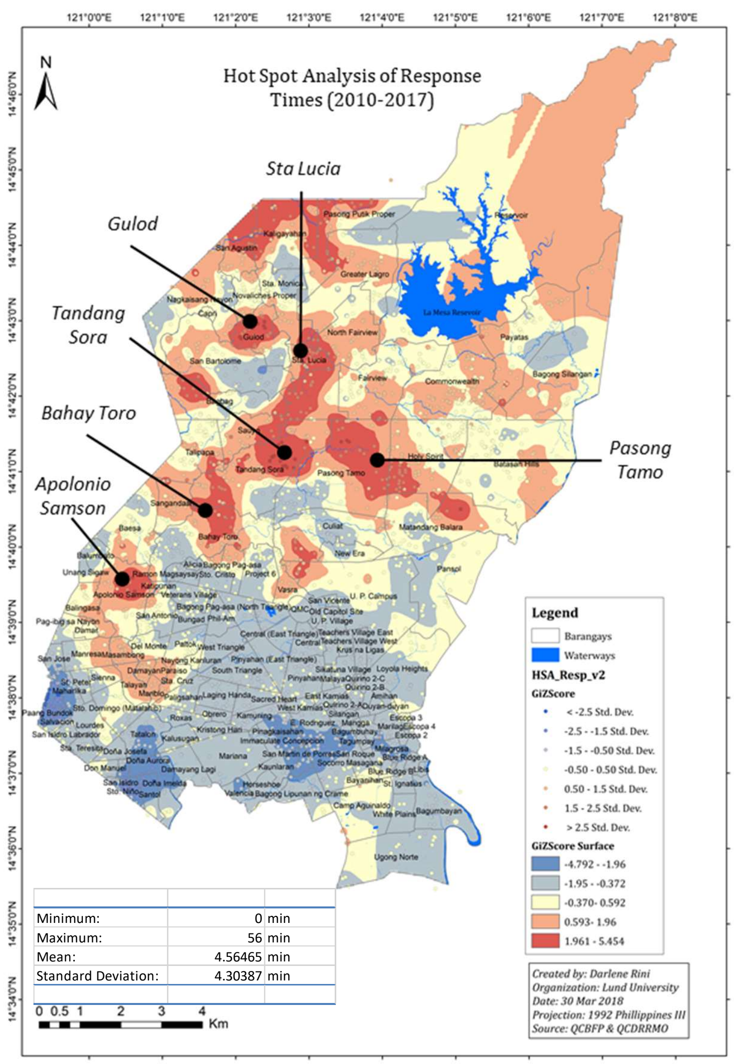



*Figure 85 – Hot spot analysis of recorded response times from actual fire incidents between 2010-2017. Areas with statistically significant response times are show in dark red, while areas with statistically significant low response times are shown in dark blue.*

## D.4 Socio-Economic Data Correlation Analysis

As was described previously, the land area and residential population of barangays in QC vary widely, from 0.013 $km^2$ to 26 $km^2$ and 0 to 186,469 people, respectively. While the barangays are geographically stable over time, the major differences in area and population cause significant area unit issues for a regression analysis. This is because data aggregation necessarily generalizes spatial patterns, preventing individual-level interpretation and leaving data analysis subject to the choice of areal units. That is, point data aggregated to a different spatial levels/unit may display different patterns (Openshaw, 2004/1&2). In QC with the large variations in barangay areas, spatial analyses done at the barangay level tells a different story to spatial analyses conducted on uniform aggregation areas (e.g. 1$km^2$ areal units or at point incident level) performed in Section 7.2.1 - 7.2.3.

In Figure 86, point fire incident data was aggregated to the barangay level for all fire incidents and for severe fires only (i.e. 1st Alarm fires and higher). In these figures, high fire counts seem to occur primarily in the larger barangays. While this makes sense (i.e. larger areas of land, generally have more people and therefore more sources of fire ignition), it does not correlate to the hot spot analyses (Figure 50 and Figure 51) where high fire concentrations are not definitively linked to the largest barangays. While a regression analysis would still help explain total counts of fires, it would not explain the high concentrations observed in the hot spot studies, which are more critical from a management perspective. Similar observations were seen for maps of fires normalized by barangay area.

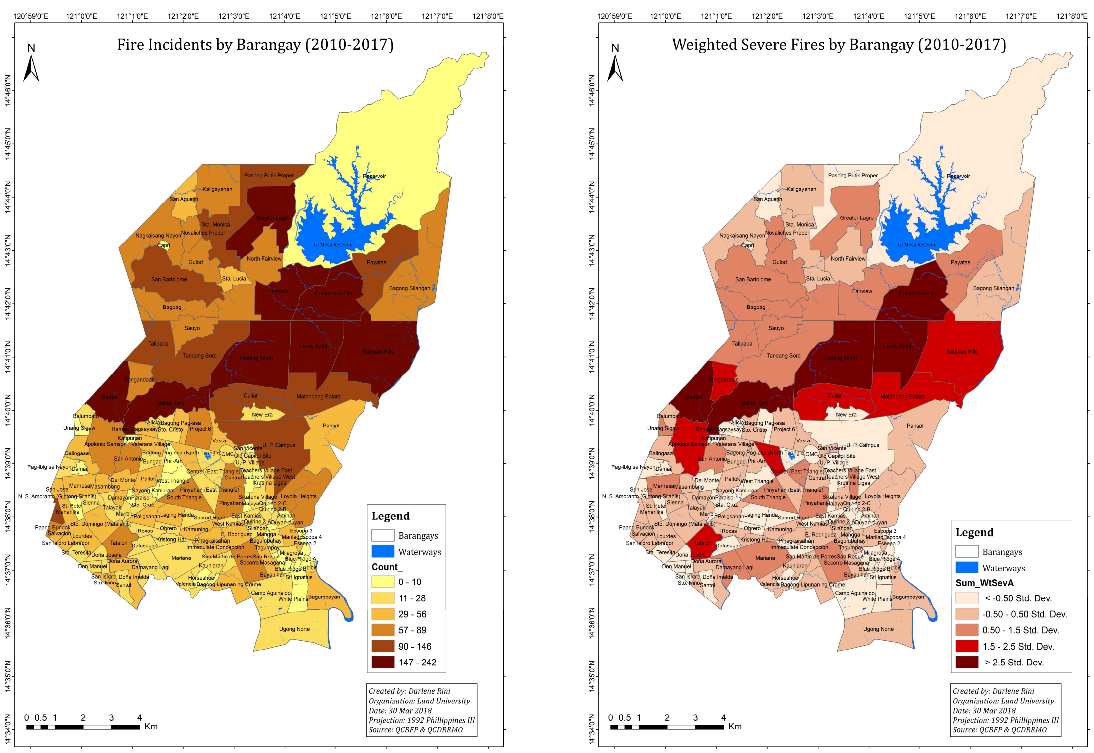



*Figure 86 – Spatial distribution of all fire incidents and weighted severe fire counts by barangays.*

In addition to evaluating the data aggregation issues in the regression analysis, fire incidents and severe fire incidents were normalized against barangay area to evaluate data aggregation based on fire density. See Figure 87. In these maps, high rates of fire density appear to be in the smaller barangays in the more central part of the city, which does not correlate with the high fire concentration areas from the hot spot analyses, or the KDE maps in **Figure 46** and **Figure 47**. This also suggests that data aggregation to the barangays, even when normalizing against area still reveals issues with areal units being too large to capture detailed fire hot spots.

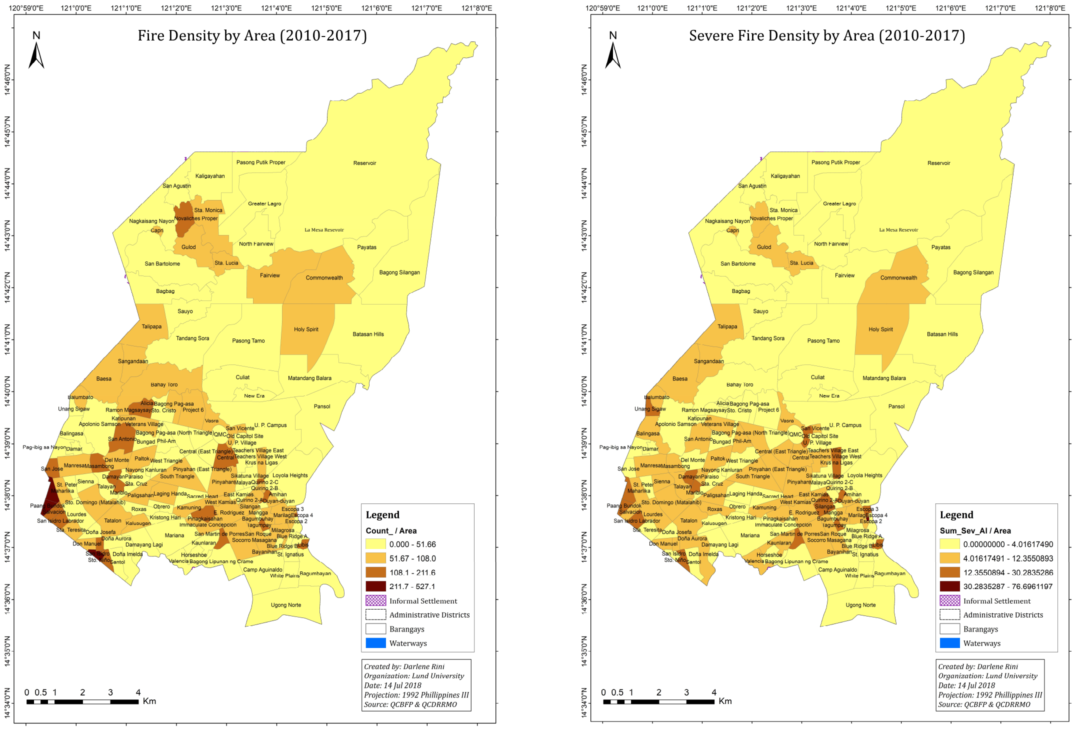



*Figure 87 – Spatial distribution maps of dependent variables – (Left) fire density and (Right) weighted severe fire density by barangays density.*

In addition to inconsistent areal units, large aggregating areas can also be problematic as they diffuse differences in demographics, socio-economic profiles and fire risk landscapes. This is explored further in the discussion section.

Furthermore, the fire incident and fire density histograms (as also provided in Figure 88 and Figure 89) also illustrate that data does not follow a normal distribution needed for linear regression analysis. While a log transformation can be applied to convert the data values in an approximation of a normal distribution (as was done in Figure 89) the issue of the barangay scale and inconsistent areal units would result in misleading results in any event.

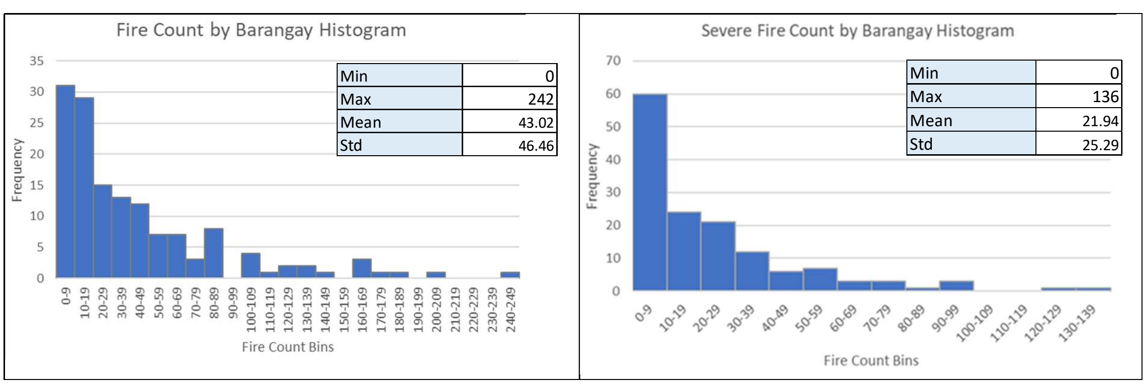
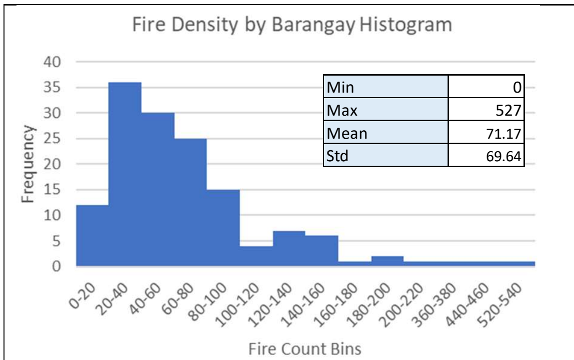
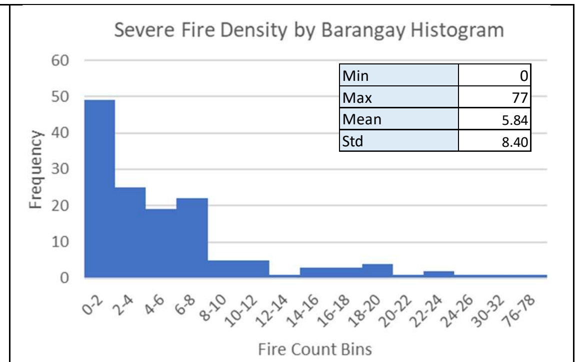



*Figure 88 – Histogram of fire counts and weighted severe fire counts.*



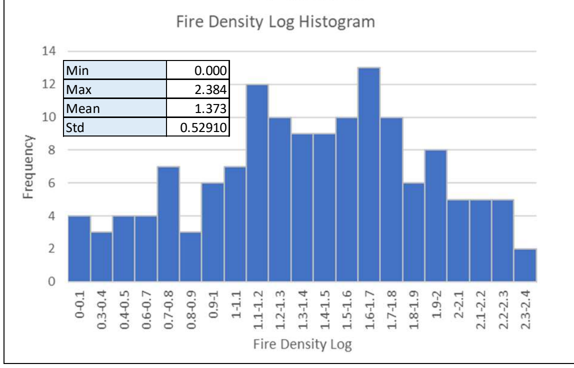




*Figure 89 – Histograms of fire density (top left) and severe fire density (top right). The log transformation was applied to convert the original values of the fire density variable to an approximate normal distribution (bottom left).*

***Note: While writing these results a better correlation between the hot spot analysis and aggregating fires by barangay occurred when the city was divided in North and South regions. This is because the northern barangays are mostly of a simlar size to each, as are the southern barangays.***

A better correlation between the hot spot analysis and aggregating fires by barangay occurred when the city was divided in North and South regions. This is because the northern barangays are mostly of a simlar size to each, as are the southern barangays. Figure 90 illustrates the improved correlation. A regression analysis was performed between the explanatory variables in Table 27 and severe fire events. In this analysis, several statistically significant models were produced that correlate the explanatory varables to severe fire incident.

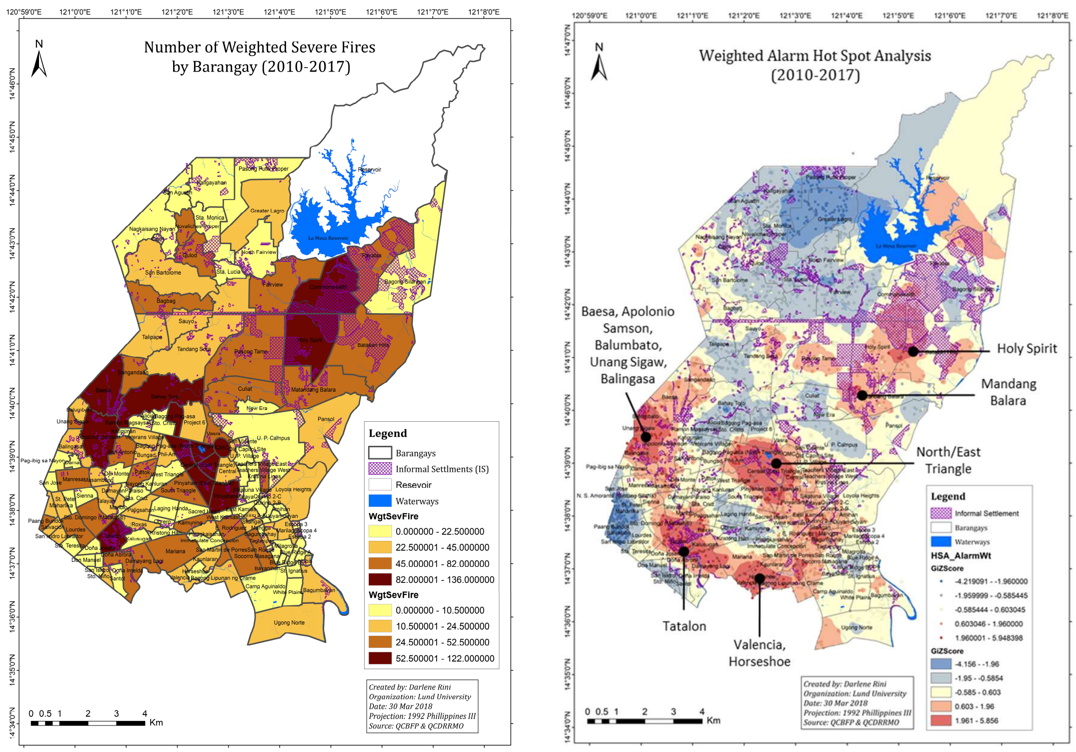



*Figure 90 - Improved correlation between hot spot analysis of weighted severe fire events and aggregating by barangay, where the city is split into northern and southern regions.*

## D.5 URDI Supplemental Results Data

This section provides some of the supplemental data used assess the urban fire risk index for QC. The follwoing table provides the assumed weights for each indicator. Most of the weights (except for the firefighting vulnerabilities) were based on those identified in the HVRA analysis commissioned by the QCG. Based on that study, the weights were determined using focus group discussions and reaching consensus among several local QC emergency service, DRM, and other relevant stakeholders/experts in the city.

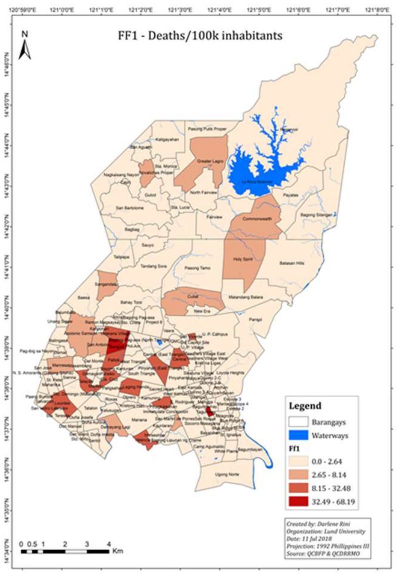
| Population Losses (Weight = 0.6) | Indicators | Weight |
|---|---|---|
| Fatalities | **RE1:** Casualties given as number of fatalities per 1000 in a Barangay | 0.7 |
| Injuries | **RE2:** Injuries given as number of fatalities per 1000 in a Barangay | 0.3 |
| Impacted Families (DISCARDED) | **RE3:** Impacted Families; given as the number of families impacted by fire per Barangay area | N/A |
| Building Losses (Weight = 0.4) | Indicators | Weight |
| Direct Economic Losses | **RE4:** Economic Losses; given as the per capita direct economic losses in a Barangay | 0.6 |
| Affected Buildings | **RE5**: Affected Buildings; given as the ratio of affected buildings to the total building stock in a Barangay | 0.4 |

| Social Vulnerability (Weight = 0.7) | Indicators | Weight | |
|---|---|---|---|
| Vulnerable Groups | **SV1:** Disabilities given as the ratio of persons with disabilites and chronic illness in a Barangay | 0.35 | 0.4 |
| | **SV2:** Children as the ratio of Chidren (age group 0-9) vs total population | 0.25 | |
| | **SV3:** Elderly given as the ratio of elderly (age group 65 and over) vs. total population | 0.25 | |
| | **SV4:** Urban poor as the ratio of families in informal settlements vs. total households | 0.15 | |
| Urban Congestion | **SV5:** Population density given as the population in a Barangay divide by area (km2) | 0.25 | |
| Education | **SV6**: No education given as the ratio of population 10 years who have not completed any school | 0.15 | |
| Sub-standard Housing | **SV7:** Dilapidated Housing given as the ratio of dilapidated housing plus those in need of major repairvs total buildings in Barangay | 0.1 | |
| Crime | **SV8:** Crime given as the total indexed crimes in a Barangay per capita | 0.1 | |
| **Coping Capacities (Weight = 0.3)** | **Indicators** | **Weight** | |
| Hospital Capacity | **CC1:** Hospital Beds given as the number of hospital beds in a Barangay | 0.7 | 0.25 |
| | **CC2:** Hospital Accessibility given as the Travel Time given as the time it takes to travel from the nearest hospital to the centroid of a Barangay | 0.3 | |
| Firefighting Capacity | **CC3:** Firefighting Service Area given as the Travel Time for a firefighting apparatus/staff to reach all areas of the Barangay | | 0.5 |
| | **CC4:** Hydrant Coverage given as a ratio of the land outside range of presriptive guidelines to total land area of Barangay | | |
| | **CC6:** Staff given as the number of provided staff vs total recommended by government and international standards | | |
| | **CC6:** Stations given as the number of stations provided vs. the number recommended by government standards | | |
| Prevention/Mitigation Capacity | **CC7:** Fire Protection Projects given as the amount in PhP of contracted awards for completed and planned risk mitigation projects | 0.25 | |

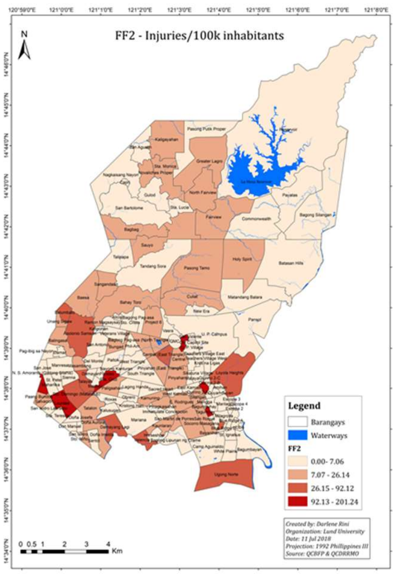
## D.6 Indicators and assumed weights for each indicator and sub-indicator

### Fire Physical Index ($R_{F_f}$)

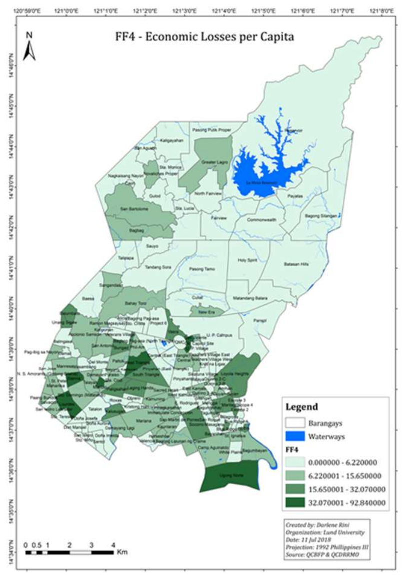
$$R_{F_i} = \sum_{j=1}^{n} R_{F_j} \times w_j$$



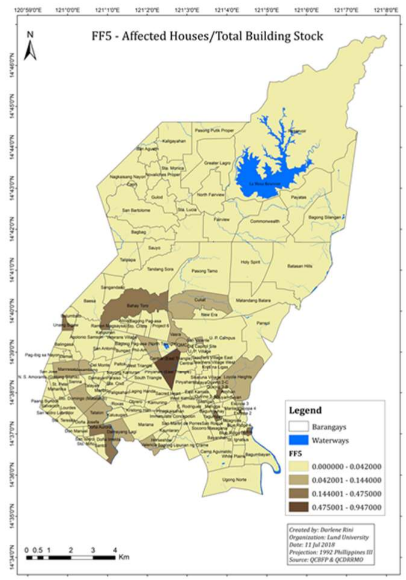

*w = 0.7*




*w = 0.3*



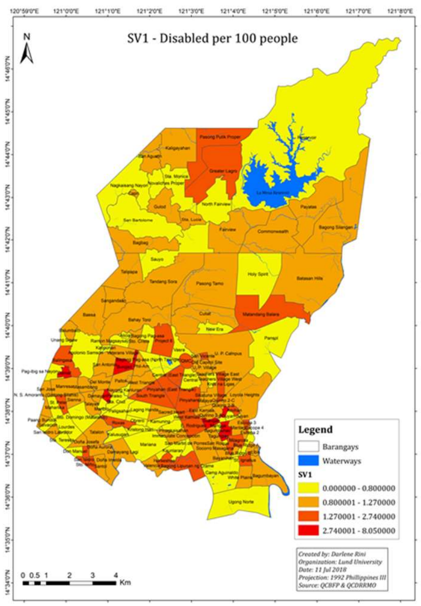

*w = 0.5*



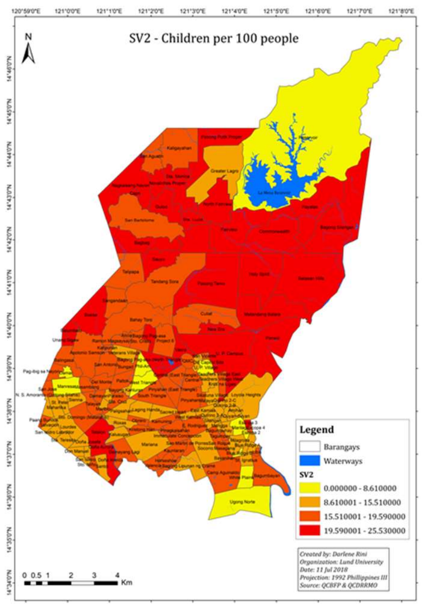

*w = 0.5*

*Fire risk index ($R_F$) = (Deaths x w) + (Injuries x w) + (Economic loss x w) + (Affected Houses x w)*

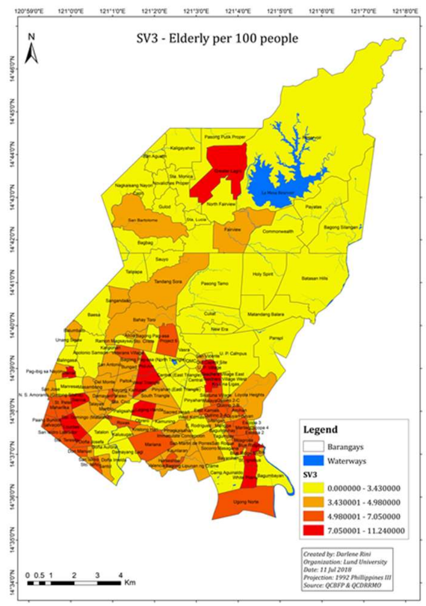
## Vulnerable Groups Index $F_{f_k}$



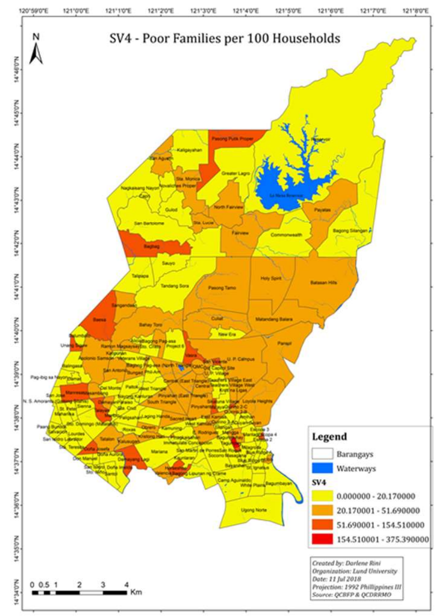

*w = 0.35*




*w = 0.25*




*w = 0.25*

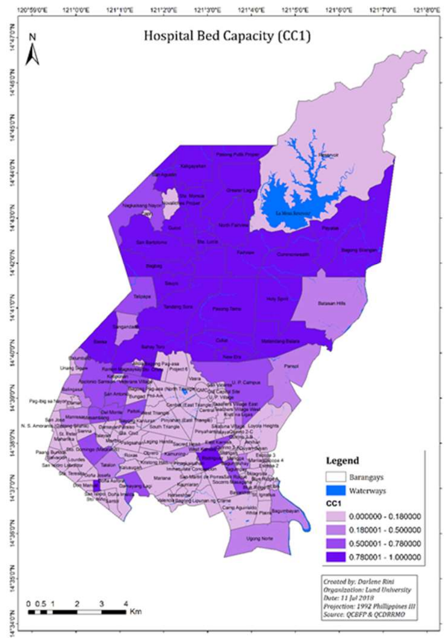



*w = 0.15*

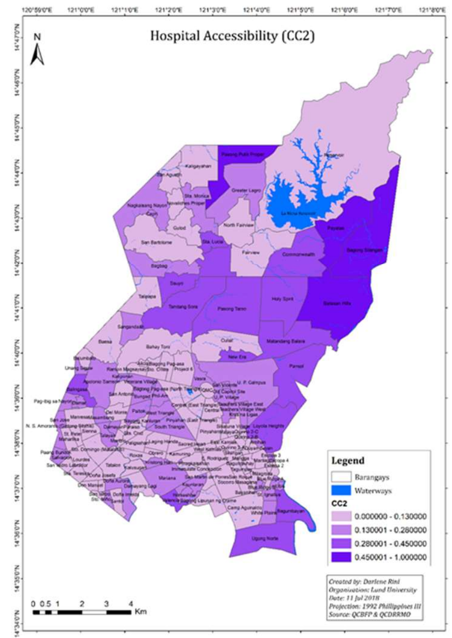
*Vulnerable Groups* $(F_{f_k})$ = *(Disabled x w) + (Children x w) + (Elderly x w) + (Poor x w)*

## Hospital Capacity Index $F_{r_2}$

- *Linear transformation based on performance criteria of 5 hospital beds per 1,000 people*
- *No performance criteria for hospital accessibility*



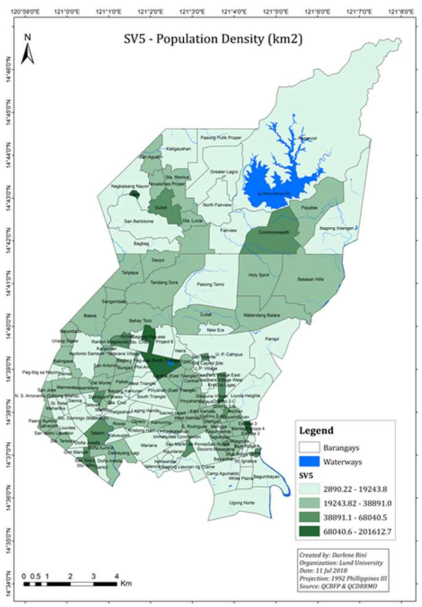

*w = 0.7*



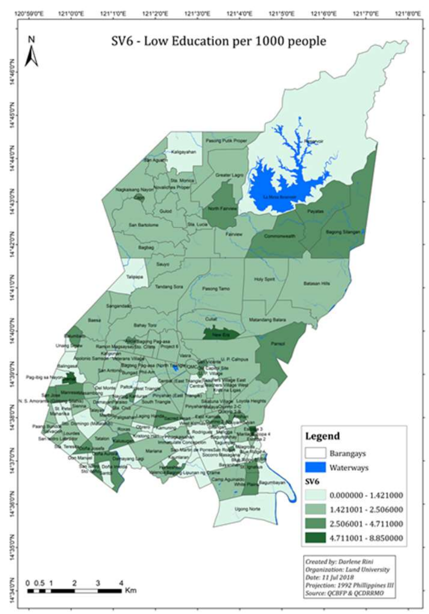

*w = 0.3*

*Lack of Hospital Capacity Index ($F_{r_2}$) = (Hospital Beds x w) + (Hospital Distance x w)*

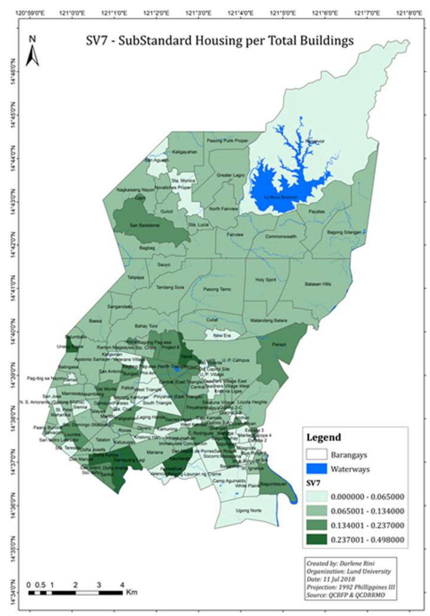
## Social Vulnerability Indicators



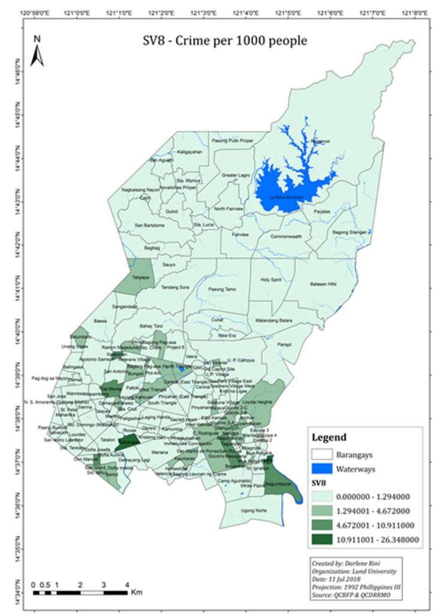

*w = 0.35*




*w = 0.25*



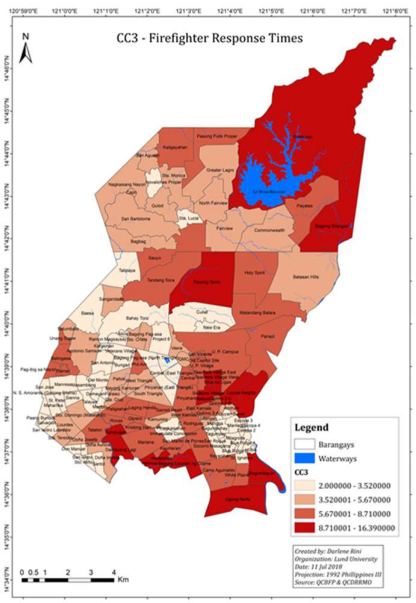

*w = 0.25*



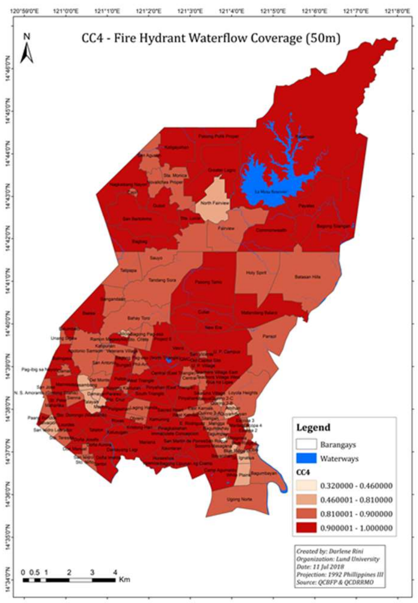

*w = 0.15*

*Social Vulnerability Indicators* ($F_f$) *= (Pop Density x w) + (Education x w) + (Sub-stand. House x w) + (Crime x w)*

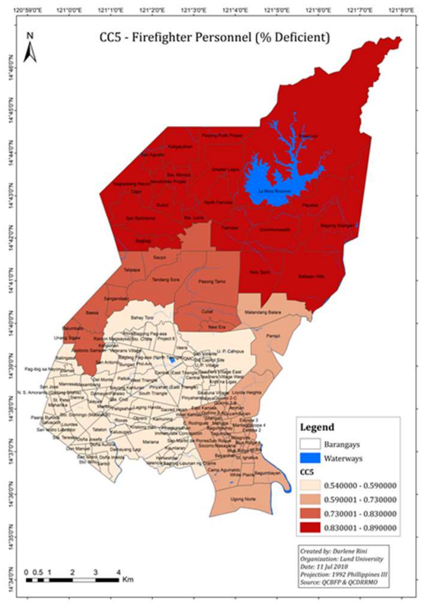
# Fire Fighting Index $F_{r_3}$



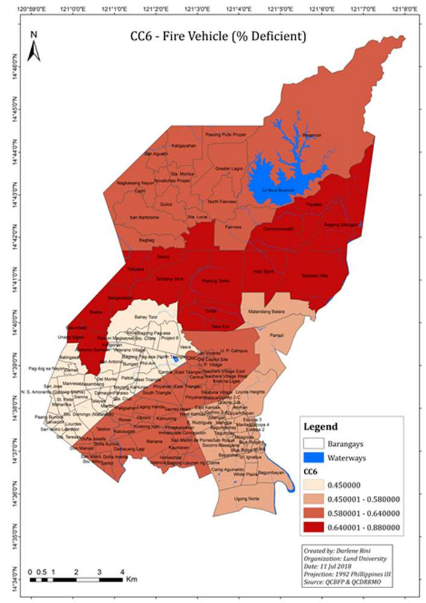

w = 0.35




w = 0.25




w = 0.25

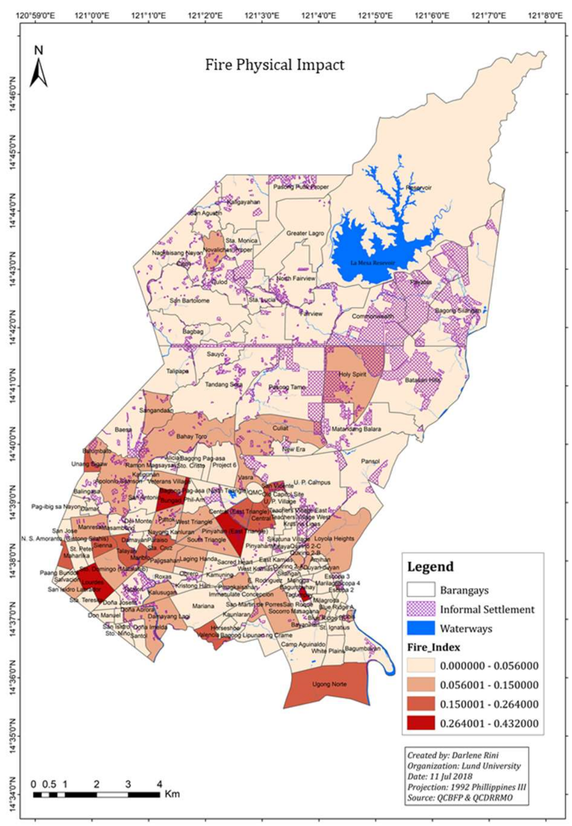


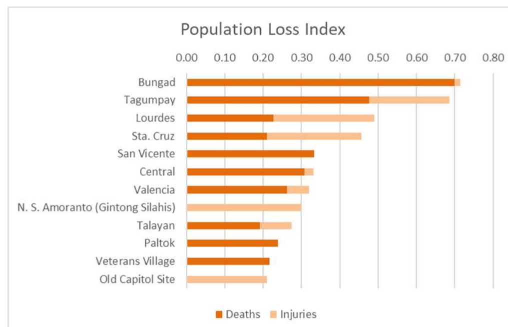

w = 0.15

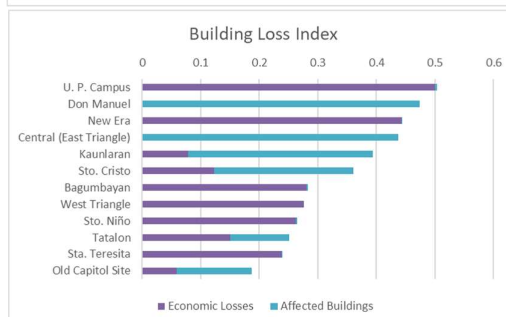
*Lack of Fire Fighting ($F_{r_3}$) = (Response Time x w) + (Hydrant Coverage x w) + (Staff x w) + (Trucks x w)*

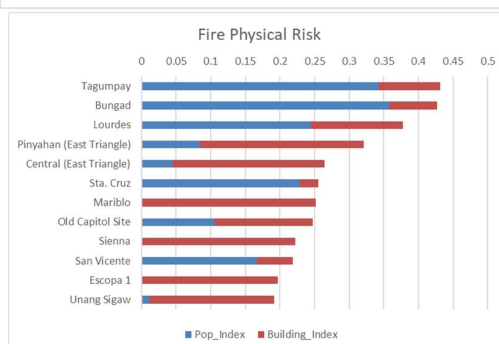
## D.7 Sensitivity Analysis – URDI Method for Fire Risk

The following diagrams are from a sensitivity analysis of the fire physical impacts whereby the weights for the economic losses and affected building were assumed to be 0.5 each (as opposed to 0.6 and 0.4, respectively in the base case). The weight factors for the population index and building loss index were also assumed at 0.5 (as opposed to 0.6 and 0.4 respectively). With these weights, there appears to be some differences in the top 12 barangays, with respect to order of highest risk, but the same top barangays are still present. This indicates that the index is insensitive to shifts in the assessed weigh differences for economic losses and building loss ratio, and between population and building loss index. The index appears to be dominated by the fire losses vs the social vulnerability index. This should be evaluated more in detail in future works. Further studies should also assess variations in normalizing functions. However, the primary weakness of URDI for fire in QC is still related to the size of the barangays relative to the fire incidents and IS area scales. See Discussion for details.

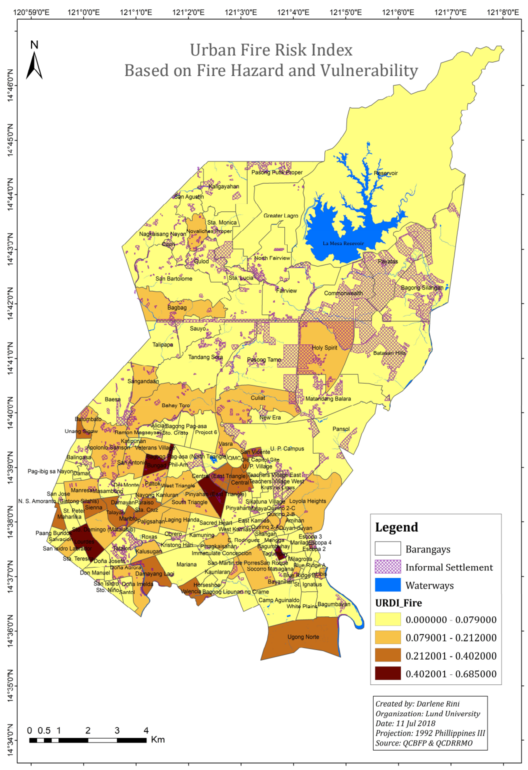


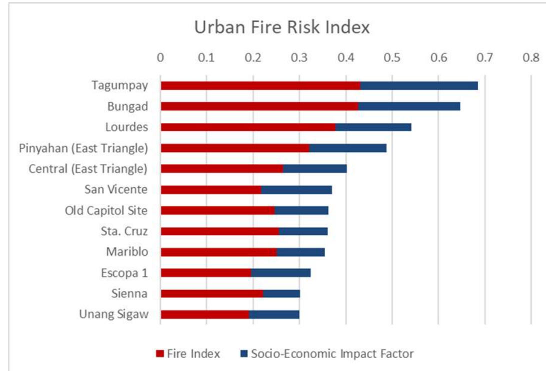




(Left) Fire physical risk based on weighted aggregation of population & building losses (Right) Top 12 Barangays for population index, building index, and overall fire physical risk




(Left) Urban fire risk index based on aggregation of fire impacts and social vulnerability (Right) Top 12 Barangays for urban fire risk index