A comparative study of fire risk emergence in informal settlements in Dhaka and Cape Town

By Danielle Antonellis, Laura Hirst, John Twigg, Sandra Vaiciulyte, Reasat Faisal, Melissa Spiegel, George Faller, Richard Walls, Natalia Flores, Birgitte Messerschmidt

Executive summary: Catastrophic fires are frequent in informal settlements around the world, where one billion people live. A complex adaptive systems framework is developed to untangle the emergence and manifestation of fire risk. Insights from case study analysis in Dhaka, Bangladesh and Cape Town, South Africa reveal the importance of interdisciplinarity, broad participation, and systems mapping when addressing safety of complex systems.

Contents

Tags: urban fire risk, conflagration, informal economy, housing, inequality, complex adaptive system, pressure and release framework, Bangladesh, Asia, South Africa

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1. Introduction

Fires are a frequent occurrence in informal settlements in cities around the world. Their consequences can be catastrophic, including lost lives (95% of fire deaths globally occur in low- and middle-income countries [1]), physical injury, and destroyed property and livelihoods. With a quarter of the world's urban population (around one billion people) living in informal settlements [2] and the everyday and widespread nature of such fires, this risk is a problem that needs addressing. However, fires are excluded from the International Federation of Red Cross and Red Crescent Societies' (IFRC) annual World Disaster Reports [3] and there is a paucity of reliable data on their incidence, impacts and causal factors [1], which has implications for effective disaster response.

In recent years, research into urban fire risk in low- and middle-income countries has grown. Fire scientists and engineers are working to understand fire behaviour, practices and interventions at household and settlement levels. Social scientists frame this issue in the wider context of urban development, and disaster risk reduction (DRR) and resilience, to understand fire risk creation and response. There is growing recognition that urban fires are not just technical and physical challenges but have complex social, political, and economic dimensions, and responses are required that take these understandings into account. This research aims to explore the complexity of the urban fire issue and bridge this socio-technical divide.

We conceptualise fire risk as socially constructed using concepts from vulnerability analysis situated in Disaster Studies (see [6] [7] [8]) and thus as a complex problem. We situate and attempt to map and understand this complexity within an urban

The city can be thought of as a system, or a system of systems, where at a basic level it is comprised of 'the urban territory, including groups of citizens, institutions, land uses, densities, infrastructures etc.' [4] It can also be expanded to include various natural (e.g., ecosystems), social (e.g., civil groups) and engineered (e.g., infrastructure) sub systems which interact. [5] Thus, transport, housing, energy, health, education, employment, politics, culture, economics, environment – each forming a system in itself – interact and relate with each other to produce complex urban phenomena. The city as complex system is understood to be an ad hoc, open system since there is no central authority, and elements and actors may move in and out of the system, regulated by multiple jurisdictions.

adaptive systems approach to disaster risk. A systems approach allows for identification of actors, relationships, and sub systems, whilst a complexity approach understands that the interactions between these are not always linear or predictable. We use this conceptualisation and its application to urban disaster risk to show the emergent complexity of fire risk and how fire safety is enacted.

The objective of this study was to conceptualise fire risk as emerging from complex urban systems, answering two research questions: 1) How does fire risk emerge in informal settlements in the two cities; 2) How is fire safety enacted in the two cities? What factors enable/disable this?

This study contributes to ongoing work to build more holistic, socio-technical understandings of urban fire risk and safety in informal settlements. Research was carried out in relation to two cities: Dhaka, Bangladesh and Cape Town, South Africa.

A multi-disciplinary team was convened to investigate the complex nature of fire risk and fire safety in informal settlements in these two cities. It was comprised of ten individual experts with collective experience in fire science and engineering, DRR, international development, urban resilience, urban planning, anthropology, sociology, geography, civil engineering, and public affairs, as well as specific research experience in informal settlements in Dhaka and Cape Town and in

other cities in Africa, the Middle East, Asia, and Central America.

The headline findings of this study are: 1) fire safety and fire risk are complex socio-technical issues requiring multiple approaches to holistically understand; 2) fire safety is a cross-cutting issue that is not fully institutionalised at community and city levels in Dhaka and Cape Town; 3) interventions for fire safety are characterised as sparse and ad hoc, without much continuity or coordination; 4) despite fire being highly contextual, common challenges and fire safety opportunities exist across diverse contexts, and adaptable methodologies exist that could contribute to improving fire safety locally.

The research is aimed at fire safety engineering and humanitarian development practitioners, researchers, urban authorities, disaster responders and disaster management agencies. It shows the necessity of understanding the complexity of fire risk emergence to support and develop contextually appropriate fire safety measures to save lives, protect livelihoods and improve well-being.

2. Contextualising fire risk in informal settlements

The speed and scale of urbanization in low- and middle-income countries, together with population growth, put considerable demands on urban systems. Socio-economic and political regimes mediate the ways in which cities provide residents with the means to live well. Demand for adequate, affordable housing often outstrips supply. In response, informal settlements[1] of

Figure 1. Damage after March 2017 fire in Imizamo Yethu; Photo Credit: Sullivan Photography

It is important to recognise that informal settlements do not exist entirely outside of the state, nor are they the 'opposite or absence of urban formality' (*p.125*) [10]; they are produced by state decisions and processes of exclusion and interact in different ways with 'formal' actions and components of cities and the state. A spectrum of informality exists, which results in diversity across and between informal settlements, materially, economically, and politically. Recognising this spectrum and diversity of experiences and conditions is vital for complex systems approaches.

self-built, often poor-quality houses or shacks develop outside the purview of state legal systems of land ownership and tenure, and of planning, land use, building and public health and safety regulations [9], and may experience one or more of the following deprivations: (1) inadequate access to sanitation and infrastructure (2) poor structural quality of housing, often self-built, (3) overcrowding, and (4) insecure residential status

[2]. Within this context, fires are a regular occurrence.

Imizamo Yethu (**Figure 1**) is a large informal settlement located in the Greater Hout Bay Valley area of Cape Town. The settlement is surrounded by affluent suburbs, but within the informal settlement, residents lack basic services and infrastructure. [11] Since its establishment in 1991, Imizamo Yethu has experienced many fires, which have caused major losses of life, property and possessions. [11] A fire on March 11, 2017, killed 4 people, destroyed 2,194 structures and left 9,700 people homeless. [12] This fire is considered the

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1 This research uses the term 'informal settlement' throughout but recognises the wide usage of terms to refer to human settlements of the nature described, which are acceptable to greater and lesser extents in different contexts (slums, shacks, etc). It also recognises the term 'informal' does not exactly describe the reality of the spectrum of (in)formality that exists in such places. The research uses the term 'informal settlement' in the South African context to refer to unplanned areas, including those found within wider areas such as townships, which can encompass formal, backyard and informal housing.

most devastating fire that ever occurred in Imizamo Yethu and was unprecedented in terms of scale and response. The fire lasted over 13 hours before the fire services were able to extinguish the flames, leaving mass destruction in its wake. [12]

Korail (**Figure 2**) is the largest informal settlement in Dhaka, Bangladesh with a population density of 322,000 people per square mile, over 4.5 times higher than that of Imizamo Yethu in Cape Town. [13] Fires frequently affect Korail; in March 2017 a fire in destroyed 4,000 dwellings and displaced an estimated 20,000 people. [14]

This brief overview of fires in the two case study cities illustrates the scale of fires in informal settlements and the importance of this research.

Figure 2. A fire in Korail informal settlement in December 2016; Photo Credit: BRAC

3. Fire risk as hazards interacting with vulnerabilities

This section introduces the conceptual framing used to understand fire risk, bringing together the Pressure and Release (PAR) Framework used in Disaster Studies and the Complex Adaptive Systems (CAS) approach, and shows how these two frameworks can be brought together to identify fire hazard, human vulnerability, and their complex relationships, before, during and after fire.

3.1 Pressure and Release (PAR) framework

Within disaster studies, the Pressure and Release framework (PAR) [15] (Figure 3) is a key tool for understanding the interaction of hazards and vulnerabilities. It is based on the premise that disaster risk emerges from the intersection of two opposing forces: vulnerability on one side and a natural hazard on the other, creating pressure and thus disaster risk. [16]

Vulnerability generally refers to the characteristics and circumstances of a group, system, community, or asset that make it susceptible to the damaging effects of a hazard [17]; as well as the ways in which people are able to anticipate, cope with, resist and recover from a hazard [15]. Therefore, **vulnerability in this context** is a sum of wider contributing factors given that informal settlement residents live with many deprivations, including inadequate water, sanitation and infrastructural access, insecure residential status, as well as a lack of access to social, economic and political resources, underpinned by overlapping and intersecting conditions of urban poverty, inequality, and marginalisation. [15]

In the PAR, **root causes** are interrelated political, social, and economic structures within societies and economies, which affect the allocation and distribution of resources, wealth, and power among different groups of people; while **dynamic pressures** are more immediate processes and activities that translate the impacts of root causes, temporally and spatially, into unsafe conditions. Fragile livelihoods and unsafe conditions are the manifestations of the multiple ways in which vulnerability is expressed in time and space in concurrence with a hazard. Disaster risk is understood as "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity". [18] Finally, hazards are presented as existing in their own right, but also accentuated by the progression of human processes/vulnerabilities. The PAR framework offers a comprehensive entry point for identifying how vulnerability interacts with a hazard (**Figure 3**).

The PAR is used here in the context of fire risk in informal
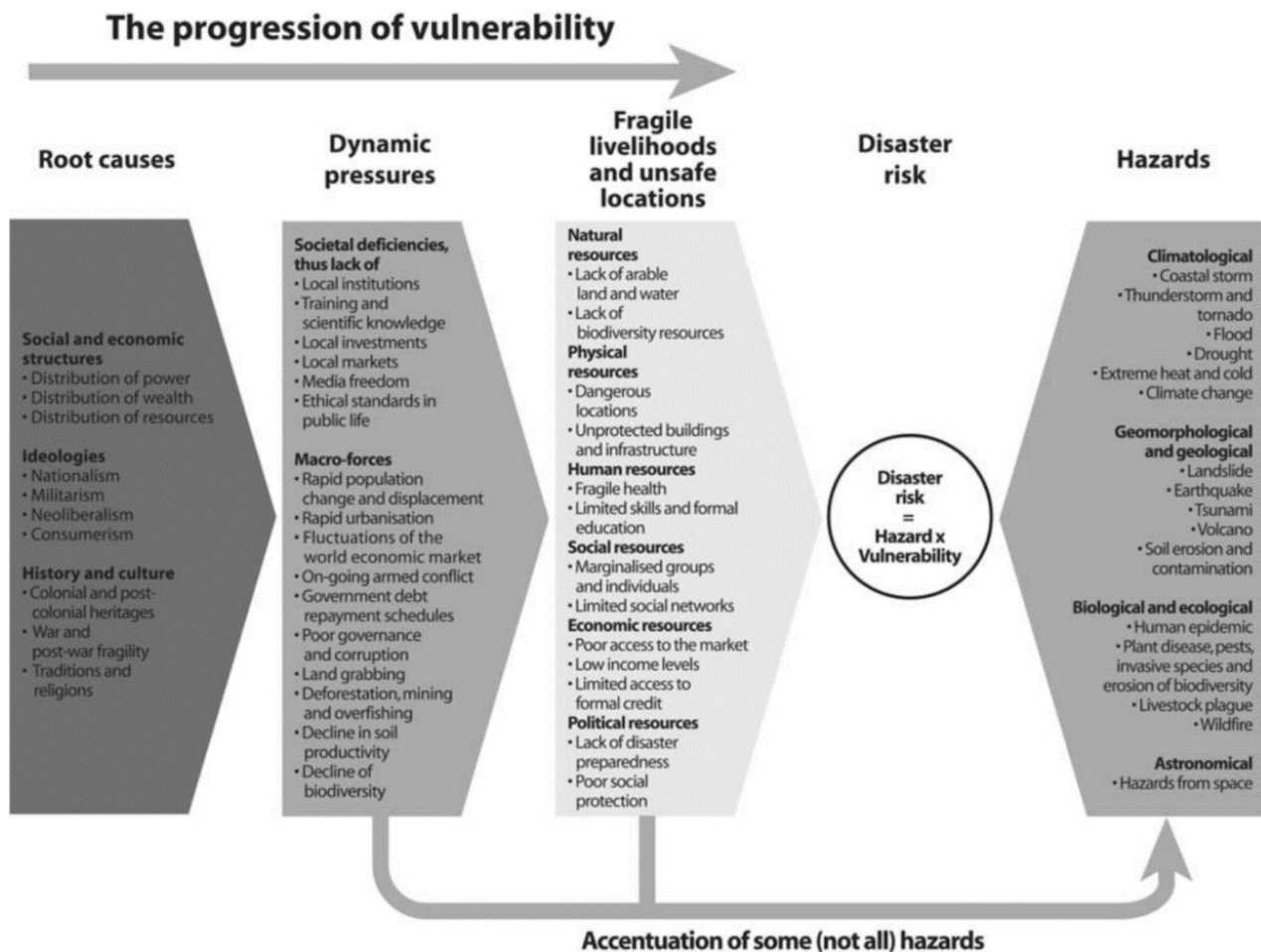
The progression of vulnerability

Figure 3. Pressure and Release Framework [7]

settlements in order to identify fire hazards, vulnerabilities, and their interactions, as well as root causes and dynamic pressures holding these conditions in place. While the PAR is widely used in disaster management planning and as a research tool, its use in this particular context of urban fires is novel.

However, the PAR is limited in its ability to capture the full complexity of fire risk in informal settlements because it separates the production of hazards from social processes, which does not address the way in which urban fire hazards arise as a result of human decisions and activities. Urban fire hazards are not exogenous. Rather than an external hazard triggering a disaster event by interacting with unsafe conditions and fragile livelihoods, urban fire

hazards emerge through a series of intersecting processes in the same way as vulnerabilities.

Figure 4 is an adapted PAR for urban fire contexts showing that fire hazards, as well as vulnerabilities, are the result of systemic and interrelated political, social, and economic structures within a society and economy. These structures affect the allocation and distribution of resources, wealth, and power among different groups of people (root causes) and the processes and activities that translate the impacts of these root causes, temporally and spatially (dynamic pressures). The urban fire adaptation has been transformed into a sphere where root causes and dynamic pressures lead to the creation of both fire hazards and vulnerabilities, and therefore

fire risk. This maintains the most central concept of the PAR, that risk emerges from the intersection of two opposing forces: vulnerability and a hazard, creating pressure and thus disaster risk. [16]

Another limitation of the PAR is that it presents a linear progression of risk emergence as opposed to acknowledging a potentially more complex and nonlinear progression. To address this, the PAR is enhanced with principles derived from complexity approaches, explored in the following section.

3.2 Complex Adaptive Systems (CAS) and urban fire risk

Current urban resilience discourse broadly considers the capacity of a city's systems to survive, adapt and grow in response to stresses and shocks they may experience. The impact of fire tends to be neglected
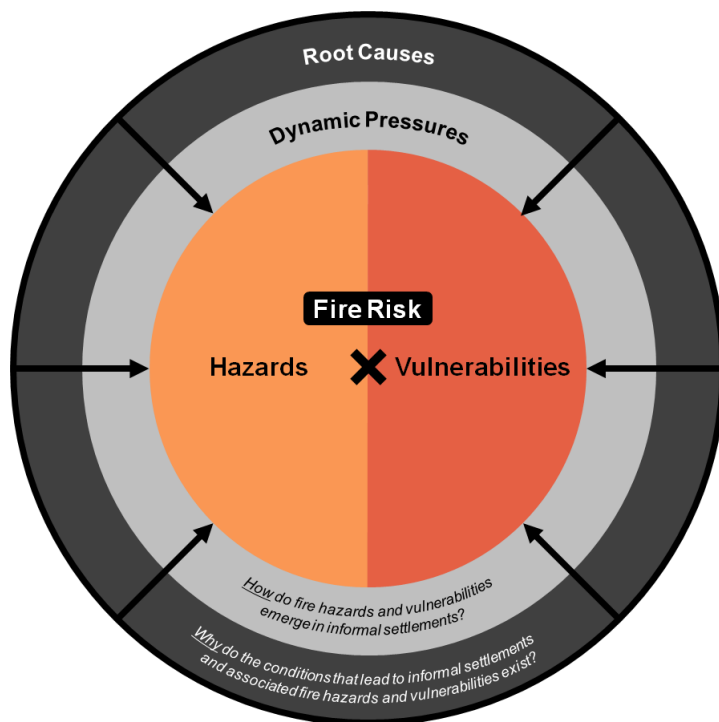
Figure 4 Adapted PAR for Urban Fire context.

as well as considerations of how fire risk is produced and how systems do/do not adapt to fire risk. This work is therefore a vital contribution to building urban resilience knowledge. As discussed, fire risk arises from the mutual interaction between hazard and socio-economic vulnerability. To understand the wider and underlying social, economic, and political situation underpinning this interaction a complex adaptive systems (CAS) approach is used here.

Complex adaptive systems (CAS) theory builds on traditional (linear) systems theory to attempt to understand non-linear adaptations which produce complex, sometimes unforeseeable, emergent behaviours, practices, patterns, and adaptations over time. It enables analysis and interpretation of social dynamics by focusing on diverse interacting components (sub-systems), their feedback loops and self-organisation. [19] [20] [21] A CAS approach can help to explore the interactions and relational flows

between individual elements and the system's potential to adapt and respond reflexively to internal and external changes [21]. It can therefore be a useful approach to investigate complex interactions between fire hazards and vulnerabilities that lead to fire risk and ultimately fire incidents.

Whilst informal settlements have traditionally been understood as apart, or excluded from formal, regulated city boundaries, a CAS approach recognises that they are part of, and emerging from wider complex urban systems and are indeed functionally integrated parts of many cities [22]. The conceptualisation of the city as complex system as open, ad hoc, and relational is particularly applicable to analysing and understanding fire risk in informal settlements.

The connections and blurred lines between formal and informal parts of the city are numerous. [22] Informal settlements can be highly heterogeneous internally and across the city and the practices of the diverse people who live

there interact with and shape site-specific characteristics. A CAS approach recognises this diversity and provides a way to understand how informal settlement fire risk may manifest differently even with the same city.

A CAS approach also allows consideration of the agency of different individuals and groups within systems: an issue sometimes neglected by more technical approaches to fire risk. A focus on adaptation helps to analyse how actors within the system learn from experience, process information, and act in response [23]. These adaptations may enable or disable fire safety in informal settlements, and it is therefore important to understand them. Placing informal settlements as part of a wider CAS allows for analysis of how they can be places of productivity, adaptation, and resilience.

In seeking to visually represent a CAS approach to fire risk, the work of Butsch et al (2015) [20] is useful. Their representation of a CAS risk framework, shown in **Figure 5**, lays out a 'pre-disaster risk complex' which identifies how specific aspects of disaster risk are created. This CAS risk framework centres the disaster (material manifestation of the risk complex) and incorporates direct and indirect consequences and how they cascade in the aftermath of a disaster event. The recovery loop back to the risk complex, we understand as consequential feedback loops or adaptations which may either reduce or increase future disaster risk.

3.3 Merging the CAS and PAR approaches

A classical engineering approach would aim to tackle fire as a hazard and reduce, remove, or control elements of the fire triangle (fuel, heat, oxygen) in a technical and systematic way. However, doing so without a holistic understanding of the mutuality of fire hazard and vulnerability, the agency of
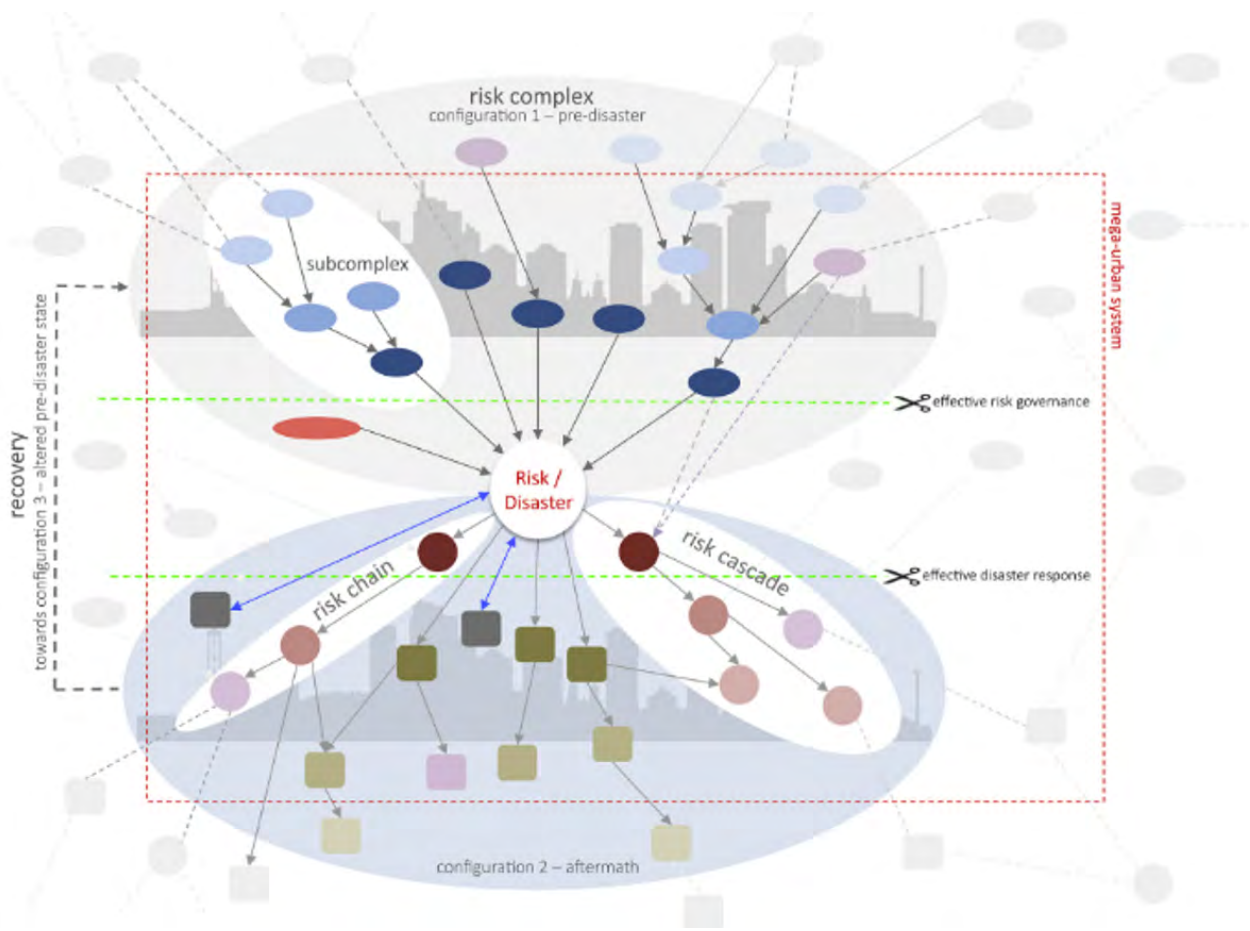
Figure 5: Visualisation of a comprehensive, complex, multi-stakeholder risk framework of a Complex Adaptive System (CAS). [20]

actors within the system, and the relational complexity, diversity and openness of urban systems can bring about unintended and damaging consequences for people already living in precarious contexts. For example, increasing separation distances between dwellings can mean demolishing households, impacting community relationships, and causing displacement; rebuilding with less risky building materials can increase costs to residents or increase eviction risk and further deepen poverty.

The PAR framework and CAS framework both offer a valuable lens to consider fire risk, but their individual limitations prevent either of them from comprehensively describing the complexity of fire risk emergence in informal settlements. On the one hand, the PAR presents a linear progression

of risk emergence as opposed to acknowledging a potentially more complex and non-linear progression; it does not allow to look at the progression of fire risk beyond its emergence to consider how fire risk manifests during or after a fire incident, nor how fire incidences contribute to further emergence of fire risk through feedback loops. On the other hand, while the CAS has the ability to identify non-linear interactions before, during, and after a fire incident, it does not distinguish between hazard and vulnerability in any detail, nor explore how these unsafe conditions emerge from root causes and dynamic pressures. Therefore, for the exploration of the systemic issues pertaining to fire risk, a combination of these two approaches is offered in this study. This enables a holistic analysis

of the issue, and more informed recommendations.

Figure 6 shows the architecture of a complex adaptive systems framework applied to fire risk, which integrates core tenets of the PAR and CAS models. This adapted framework is used throughout this study to untangle the emergence and manifestation of fire risk in informal settlements in Dhaka and Cape Town. It demonstrates how root causes and dynamic pressures lead to unsafe conditions, i.e., hazards and vulnerabilities that interact to produce fire risk. The accumulation of fire risk ultimately leads to fire incidents. Post-fire disaster consequences may cascade and feedback to further emergence of fire risk.

This examination of how risk emerges from complex adaptive systems provides
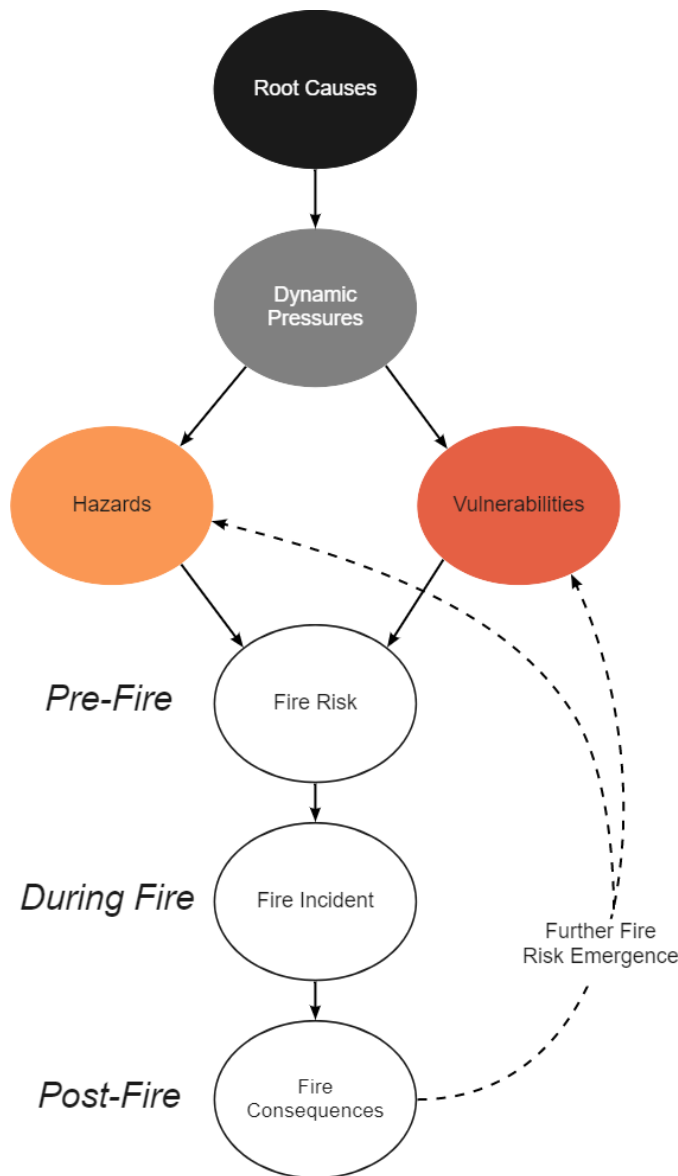
Figure 6: Fire risk complex adaptive systems framework

a vital contribution to urban resilience knowledge. The study's methodology and framing complements urban resilience discourse which broadly considers the capacity of a city to survive, adapt and grow in response to stresses and shocks. Not only does this mean the approach can help urban fire risk get onto the agenda of urban resilience (as it tends to be excluded), but it also offers a new approach to evaluate and address diverse risks facing cities by systematically engaging with complexity.

4. Methodology

The objective of this study is to conceptualise fire risk as emerging from complex urban systems.

Two main research questions are addressed in this study:

- How does fire risk emerge in informal settlements in the two cities?

- How is fire safety enacted in the two cities? What factors enable/ disable this?

To answer the research questions and conceptualise fire risk as emerging from complex

urban systems, an iterative methodological approach was used, employing a range of qualitative methods to understand and interrogate a wide range of socio-economic and political processes and connections.

Existing knowledge mapping

The first stage of the research brought together the project team to map existing knowledges. This was facilitated by use of the 'Web of Institutionalization', a tool for assessing and promoting the institutionalisation of cross-cutting issues in development policy and planning [24]. This tool was used to categorise and make connections between specific issues from the research team's existing knowledge and experiences in the field (see Appendix A).

A workshop to discuss the results from the 'web' exercise was convened to reflect on the issues identified, address existing assumptions and biases as far as possible; compare the two project cities; and identify the limits and boundaries of the project. This mapping exercise allowed the research group to further flesh out the adapted PAR questions by identifying initial root causes, dynamic pressures, fire hazards and vulnerabilities to explore.

Literature review

On the basis of the research questions, a Quick Scoping Review[2] of literature on fire risk

2 A QSR is a type of evidence review that lies between literature reviews and scoping reviews in terms of rigor of assessment. It aims to provide an informed conclusion on the volume and characteristics of an evidence base and a synthesis of what that evidence indicates in relation to a question. It allows questions to be answered by maximizing use of the existing evidence base, whilst also providing a clear picture of the adequacy of that evidence. It is suited to addressing challenges in meeting evidence requirements for policy and practice. [100]

and safety in informal settlements in each city was conducted. Literature in the public domain was reviewed relating to urban fire risk management and risk reduction in South Africa (principally Cape Town/Western Cape) since the end of the apartheid era (1994-present day), and Bangladesh (principally Dhaka) since the current parliamentary system was adopted (1991-present day). The review sought insights into policies and practices of urban fire management; key stakeholders and their roles, responsibilities, and mandates; perspectives of the fire problem; and ways of improving policy and practice.

The two case study cities: Dhaka, Bangladesh and Cape Town, South Africa, were selected to compare two similar fire events (March 2017 Imizamo Yethu fire in Cape Town; March 2017 Korail fire in Dhaka). However, as the research proceeded, a lack of data relating to the specific incidents (in Dhaka in particular) meant that the focus expanded to fire risk in informal settlements in each city more broadly.

Stakeholder mapping

A stakeholder mapping exercise was conducted to identify key stakeholders with perspectives relevant to the emergence of fire risk and fire safety in each city. The research team identified the relevant stakeholders (NGOs, academics, government agencies including fire services, intergovernmental agencies) who could be contacted and interviewed remotely due to the global pandemic and travel restrictions. Global pandemic restrictions together with ethical constraints ruled out any engagement with the residents for the interview from informal settlements in two countries. Thus, this research study relies on data from city level stakeholders. Based on the stakeholder mapping and insights from the interviews, further

stakeholder mapping was carried out to identify stakeholders who interact with fire and fire safety before, during, or after a fire, and their interactions and relationships in each city (the results of this particular exercise can be found in Section 5.6).

Virtual semi-structured interviews

Interviews were arranged and conducted with a range of stakeholders in each city, with interview questions derived from the research questions and with space given for issues to emerge. A list of interview questions can be found in Appendix B along with the list of the eighteen interviews carried out in Cape Town and seven interviews in Dhaka with representatives from NGOs, academic institutions, fire and rescue services, city government institutions and international multilateral agencies in Appendix C. In addition to these primary interviews, a series of pre-recorded interviews produced by Stellenbosch University and Sullivan Photography was also analysed with their permission (see Appendix C).

Each interview was attended by at least two members of the research team, with notes recorded by each. These were written up and coded according to emerging themes, with references to the research questions and themes from the preliminary literature review.

Limitations

The following limitations to the research were encountered:

- The Covid-19 pandemic impacted upon interviewees' availability and responses during the timeframe, particularly in Dhaka.

- The pandemic meant that access to residents and communities was not possible, and so this perspective is missing from the research.

- This project investigates the issue of informal settlement fires through the perspectives of professionals external to communities which does not give a holistic perspective on the issue.

- It was found that in addition to a lack of literature on the topic in Dhaka, there was also a lack of stakeholder knowledge and expertise in the topic, compared with Cape Town.

- The timeframe for the primary research was limited to 6 months.

- Interviews had to be conducted remotely and within tightly prescribed timeframes, which potentially generated a different quality of data as compared with face-to-face interviews.

5. Findings & Discussion

Building on the PAR and CAS frameworks and wider fire risk conceptualisation offered in Section 3.3, this section presents and discusses findings relating to fire risk emerging from complex urban systems, as shown in **Figure 7**.

The root causes and dynamic pressures subsection offers insights into Cape Town's and Dhaka's historical and emerging relationships with fire, emphasizing aspects of each city's history of social policy development, migration, and deprivations experienced by populations. The next subsection discusses how fire risk emerges in relation to tenure (in)security, energy, and the informal economy. Fire incident conditions, including fire dynamics as well as human and institutional responses to fire are discussed. Finally, post-fire risk chains, cascades and feedback are briefly reviewed.

This analysis concludes with a fire risk emergence complex systems map, which visually represents key aspects of fire risk emergence
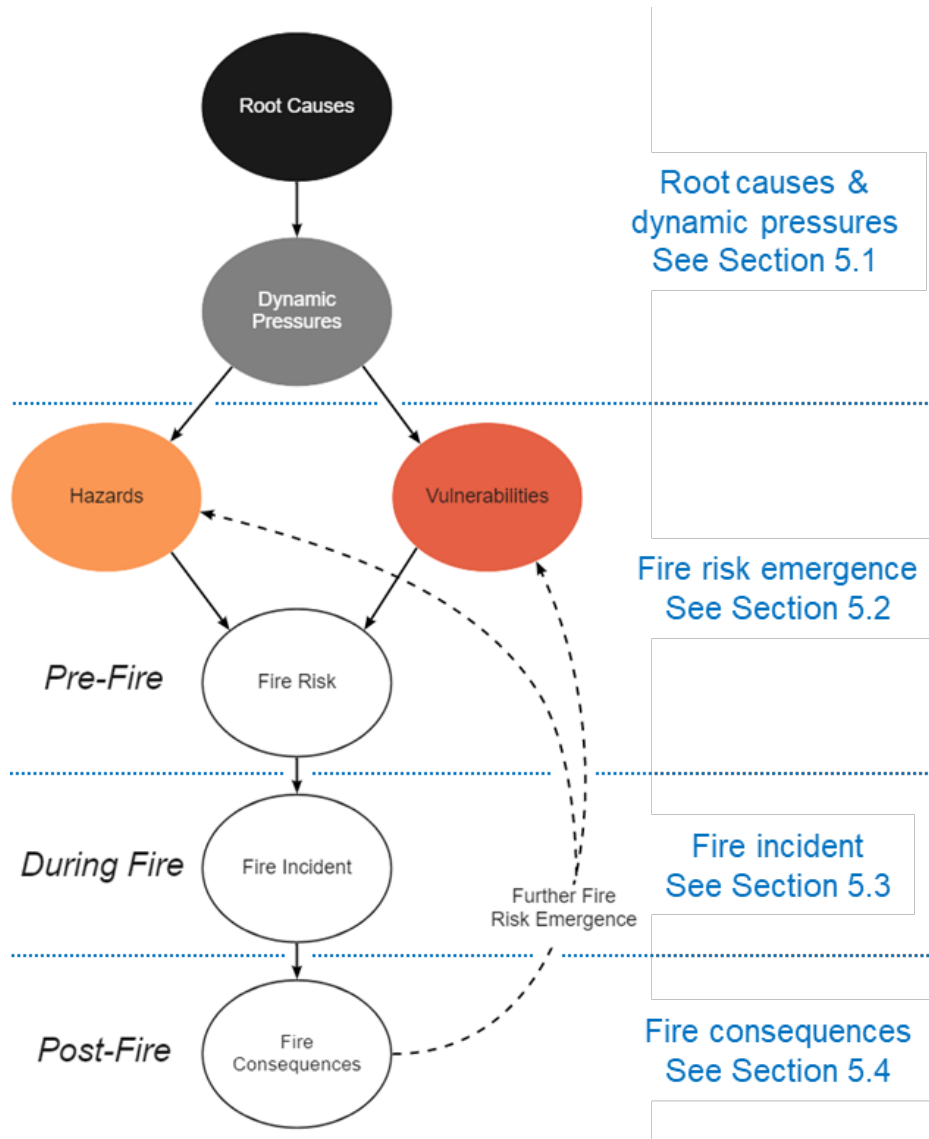
Figure 7: Section references for findings & discussion, as per the fire risk complex adaptive systems framework

5.1 Root causes & dynamic pressures

Engineering approaches to risk assessment and risk reduction rarely consider histories of people and places, or social or political dimensions of risk and safety. This can lead to negative or sub-optimal outcomes, including adverse consequences of well-intended engineering decisions. Collaboration with historians and social scientists, and participatory based methodologies, are critical to address complex societal challenges, like fire in informal settlements. A key recommendation from this work is that engineers should be exposed to other disciplines during their academic studies, and engineering training programs should prioritise developing skills for interdisciplinary working.

According to the combined PAR and CAS models (**Figure 6**) the starting point to understanding fire risk emergence is understanding socioeconomic and political contexts, including root causes (urban history, poverty, social, political & legal marginalization, etc.) and the ways they contribute to dynamic pressures, including the development of informal settlements and their respective diversity in size, location, recognition in each city.

The development of informal settlements in each city has different drivers, e.g., in Cape Town, informal settlements are partially a legacy of the apartheid era, whereas informal settlements in Dhaka are largely a function of a lack of institutional capacity for accommodating unprecedented rural to urban migration.

Figure 8: A brief urban development history of South Africa

5.1.1 Cape Town and its relationship to fire

Historical overview

The second largest city in South Africa, Cape Town is one of the nation's cultural and economic centres. Its history and development have been shaped by Europe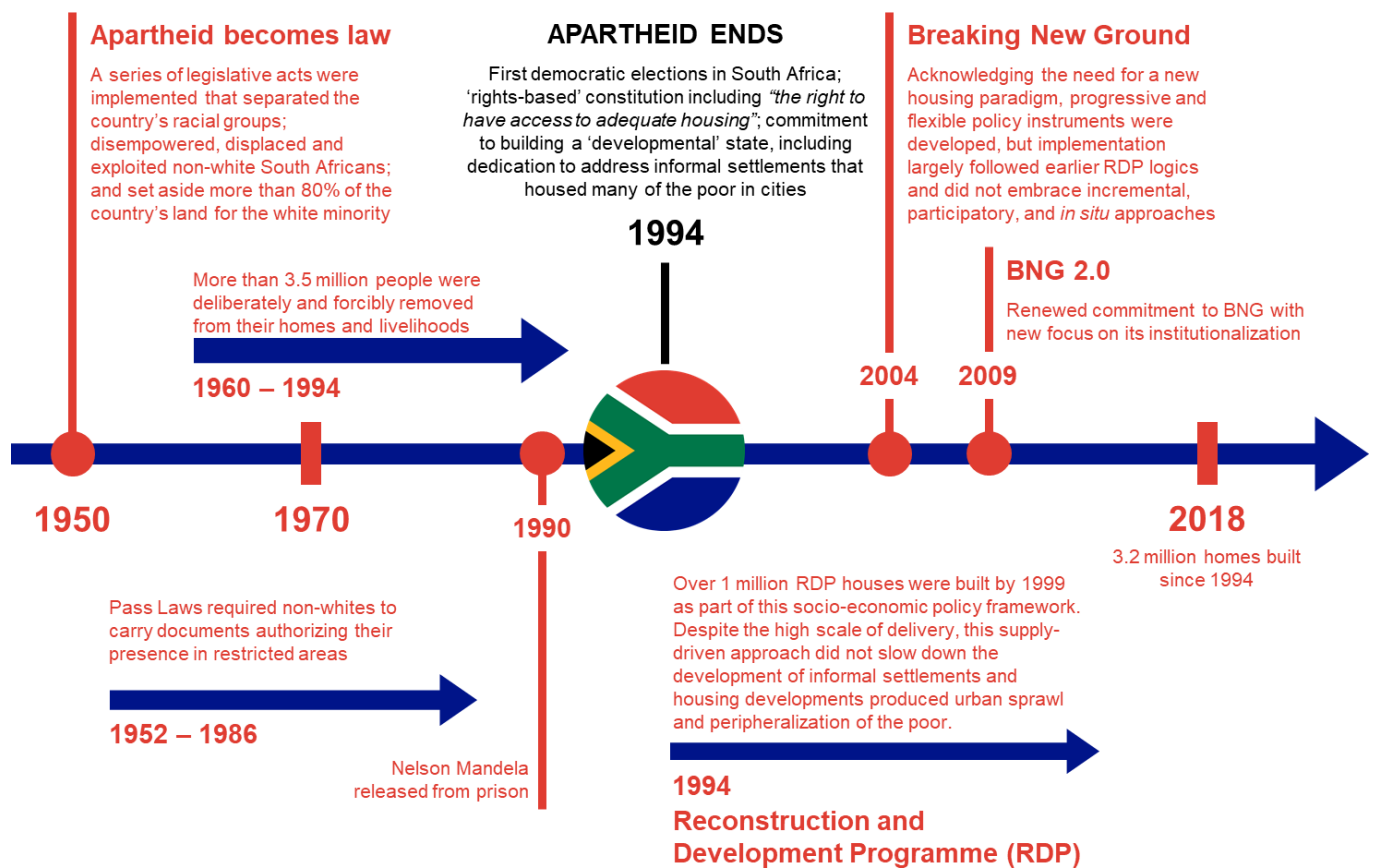an colonization, racism, apartheid, and repressive labour practices, as well as by international trade, migration, industrialization, resistance, and revolution. [25] South Africa has famously been called the world's most unequal country. The Gini coefficient of Cape Town, a measure of inequality in levels of income, is one of the lowest in the world at 0.57. [26] While unemployment, education access, and healthcare access play a role, *"the largest dividing line is land, where the legacy of apartheid meets the failures and broken promises of the current government. It's manifested most plainly in the lack of affordable housing, particularly in urban areas."* [27]

Figure 8 shows a brief timeline of key events in Cape Town. Apartheid became law in the 1950s, and one of its many legacies was the forced removal of black South Africans to racially segregated townships and settlements. Before apartheid ended, in 1990, 7 million out of 37 million South Africans were estimated to live in informal settlements, including 46.2% of urban dwellers. [28] [29]

When the apartheid era ended, provision of housing for all citizens was a priority of the new ANC government. The government's Reconstruction and Development

Programme (RDP) was the first policy document to address social development in South Africa. It prioritised reintegration of cities, access to housing and to *"modern and effective services such as electricity, water, telecommunications, transport, health, education and training for all our people." (p.8; section 1.3.6)* [30]. But since 1996 (and especially since 2005) economic policy has shifted towards market liberalisation and economic growth at the expense of urban integration and greater equality. [31]

South Africa's 1996 constitution provided a right to 'adequate housing', and the Department of Human Settlements claimed to have built 3.2 million housing units for its poorest citizens between 1994 and 2018. But the government has not been able to keep up

with the growing demand for housing, as evidenced by the ever-increasing housing backlogs. A lack of affordable housing and service delivery, and outdated urban policies (the legacy of apartheid planning) contribute to institutional failure to provide formal houses for poor communities. Informal settlements are seen as a public sector, economic and legislative failure to provide formal/improved housing, and government policies seek to eradicate them. [31] South Africa's policy of state decentralisation gives local government a key role in social and economic development. Municipalities are required to produce an integrated development programme (IDP), updated each year, which forms their guiding policy document. But local authorities face challenges in managing the haphazard nature of informal settlement development and have not been able to keep up with the increasing demand for basic infrastructural, social and health services [34]

A significant proportion of urban growth is unplanned, in informal urban settlements with low-quality buildings on land that may not be suitable for residential developments. The percentage of households living in informal dwellings in South Africa decreased relatively slowly between 1996 and 2016, but the absolute number of informal settlement households increased from 1.45 million (16.2 percent of the population) to 2.19 million (13 percent of the population). There were over 320,000 informal dwellings in the Western Cape province in 2016 [32], and according to the 2011 census, 20.5% of Cape Town's households lived in informal dwellings – with 7% in informal backyard structures (informal homes within formally planned areas, typically behind formal dwellings) and 13.5% in informal settlements. [35] [36] Informal settlement growth has been particularly rapid in some

cases: for example, the Imizamo Yethu settlement in Hout Bay, established in 1991, and originally designed to accommodate 3,000 people in brick houses on individual serviced sites, saw its population almost double between 1996 and 2001 (from around 4,600 to 8,000); and it was estimated in 2019 to have a population of up to 36,000, with a density of 228 households per hectare [37]. Growth is underpinned by internal and international migration influenced by economic and standard of living opportunities and familial ties.

The 1998 abolition of the 1951 Prevention of Illegal Squatting Act made it unlawful to evict people from their homes: individual dwellings could no longer be demolished without a court order. [38] [34] Although the law protects residents from arbitrary eviction, there continue to be unlawful (and sometimes repeated) evictions by state and non-state actors. Homes in new occupations are constructed quickly to minimize the risk of eviction.

A variety of civic organizations have influence or authority over overlapping aspects of community life. These include street committees, religious institutions, community police forums, development forums, NGOs, and social movements, which offer a platform for potential community leaders and may attempt to assert authority over everyday life, beyond the reach of the state, with opportunities for pursuing the public good as well as personal profit. [36]

Fire

Cape Town is the most fire-prone city in South Africa, with fire brigades responding to an informal settlement fire almost every day. [12]and where *"fire losses have increased significantly and appear to be on an upward trajectory" (p.4)*. [39] The number of informal settlement fires reported by fire

departments increased by over 150% between 2003 and 2018. In this period, on average 2.2 times more people died from fires in informal settlements than in formal settlements in South Africa. This is despite only 18% to 33% of the total population living in informal settlements (including backyard dwellings) [39].

In 2018, fire departments in South Africa reported 289 fatalities in informal settlements and in 2019, 214 fatalities [39]. These figures exclude unreported fires, such as the many fires residents extinguish themselves, and fires in areas protected by fire departments that do not submit fire incidence data. Furthermore, Walls et al (2020) describes: *"the total number of deaths reported by fire departments is likely to be a significant underestimation, as the aforementioned statistics are only for deaths at the location of the fire. If someone is injured in a fire and dies in hospital later this is not included in the statistics. As an example, mortuary data from 2011 showed that 2,243 people died from 'exposure to smoke, fire and flames'. In the same year, the number of deaths reported by fire departments was 410, meaning that the mortuary data is around 5-6 times higher." (p.2)* [40]

5.1.2 Dhaka and its relationship to fire

Historical overview

Bangladesh, located on the Bay of Bengal in South Asia, is one of the world's fastest growing economies today. Despite its relatively small land area, Bangladesh is the eighth most populous country in the world with 163 million people and ranks eighth amongst the countries with highest population density. [28] [41] Dhaka, the capital of Bangladesh, is a megacity with an estimated population of 22 million. The population is estimated to reach more than 31 million people by 2050. [42]

Figure 9 shows a brief timeline of key events in Dhaka since Bangladesh's independence from West Pakistan in 1971, touching on the country's political evolution over the past 50 years. During this time, Bangladesh has experienced considerable economic and population growth, and urbanization primarily driven by rural-urban migration.

Bangladesh's significant economic growth relates to rapid industrialization, especially as a Ready-Made Garment (RMG) exporter. But in 2012-2013, a RMG factory fire (Tazreen Fashions) that killed 112 people and a factory building collapse (Rana Plaza) that killed at least 1,132 people caught global attention, awakening the world to poor labour conditions facing workers and threatening Bangladesh's economy. [43] Public outrage put

pressure onto international brands and retailers supplying products from Bangladesh, and onto the local industry and government to invest in factory safety (including fire safety) and to improve labour conditions. This led to the creation of various international and national initiatives, such as the Alliance for Bangladesh Worker Safety, the Accord on Fire and Building Safety in Bangladesh, and the National Tripartite Plan of Action on Fire Safety and Structural Integrity in the Garment Sector of Bangladesh, which shared the goal to improve worker safety in the RMG sector, especially through inspections, remediations of fire, structural, and electrical issues.

Despite ongoing challenges to institutionalize progress made through these initiatives, safety improvements have made Bangladesh a more attractive

option for international clothing brands. The garment industry increased annual revenue from $19 billion to $34 billion between 2012 and 2019, a 79 percent increase revenue in the 7 years following the aftermath of these two devastating garment factory disasters.2 [44] The country is now the world's second largest RMG exporter, behind China, and this is the major driving force behind the country's economy. [45] The RMG industry plays a pivotal role in Bangladesh's socioeconomic development, employing an estimated 4.2 million workers, most of whom are migrants and women and girls (over 60 percent). [46] [47] Many of these garment sector workers live in informal settlements, especially in Dhaka.

Since Bangladesh's independence in 1971, the country has been rapidly urbanizing. Around 3.5

INDEPENDENCE

Bangladesh became an independent country after the Liberation War of 1971 with West Pakistan (today's Pakistan). Independence enhanced urbanization in Bangladesh, especially to Dhaka. The driving factors for rapid rural to urban migration was surplus labor in agriculture, globalization, drought, and systematic failure of rural agriculture and perceived opportunity in the city.

1971

45% increase in no. of informal settlements

Factory Accidents

Tazreen Fashions factory fire killed 112 workers in November 2012 and the Rana Plaza garment factory building collapse in April 2013 killed more than 1100 people. International outcries for brands to take responsibility for their supply chains and domestic commitments to secure the socioeconomic future of Bangladesh led to several factory safety initiatives — the Accord, the Alliance, and the National Initiative.

Lower-Middle Income Country

Bangladesh reached lower-middle-income status in 2015 and is on track to graduate from the UN's Least Developed Countries (LDC) list in 2026.

With over 10 million inhabitants, Dhaka became a 'mega city'

2012 2015

Dhaka is the most densely populated city in the world

1981 1985 1991

2000

2021

Ready Made Garment industry began to grow in Bangladesh

1970s Industrialization

Bangladesh Bureau of Statistics conducted its first slum census in Dhaka

New Parliament

Bangladesh's journey in the post-independence period was not smooth. It experienced turmoil in the form of assassinations, coups, counter-coups and military rule. A sharp division in political ideology took root. After a long period of instability and misrule, Bangladesh moved towards a democratic transition through parliamentary elections in 1991.

Housing Crisis

Despite the constitution including government responsibility in ensuring access to shelter for all citizens, Dhaka has no suitable large-scale models for housing that cater to the different economic groups that inhabit the city and the national housing shortage is growing rapidly:

2010: 4.6 million units / 43.43 million people
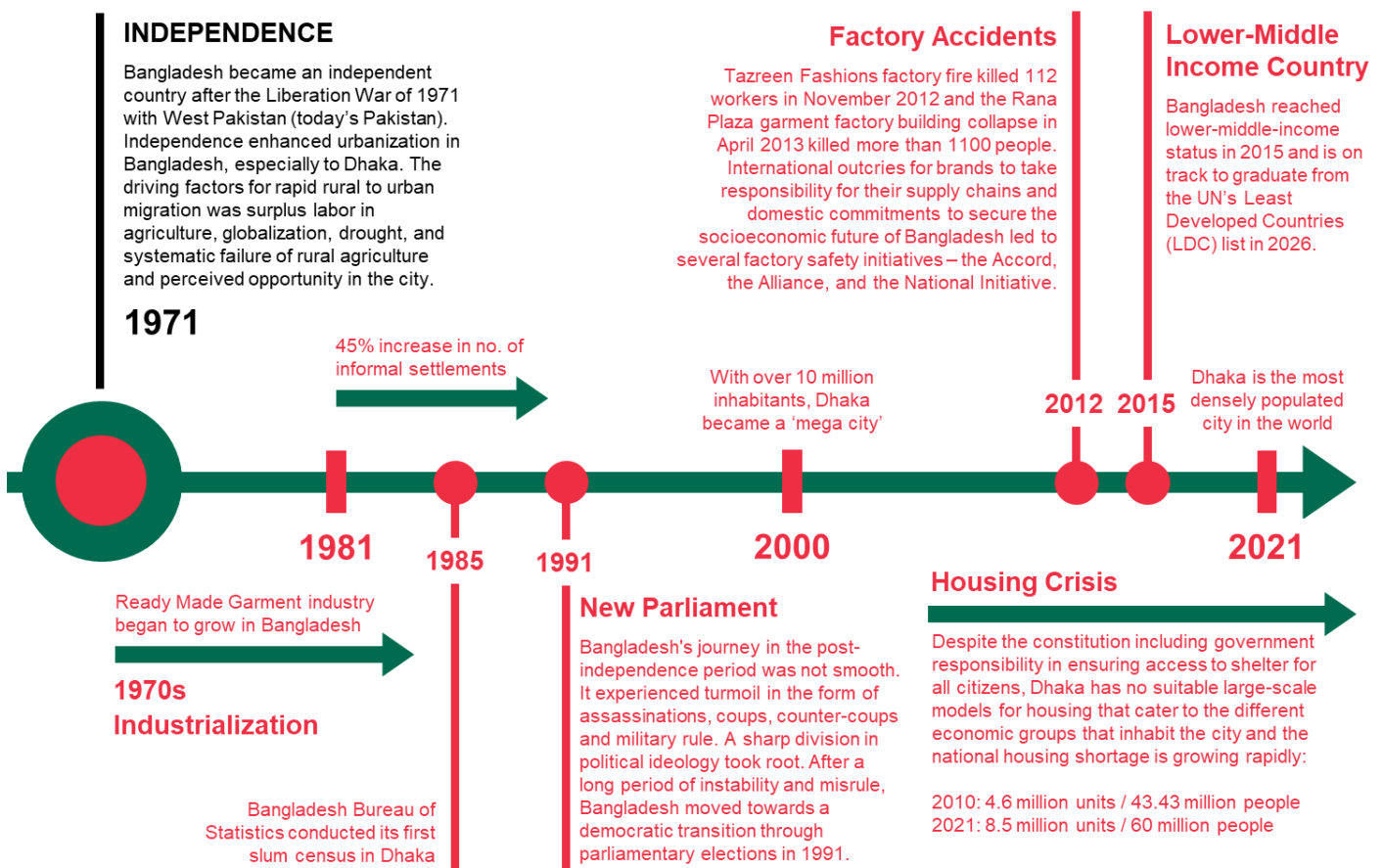2021: 8.5 million units / 60 million people

Figure 9: A brief urban development history of Dhaka, Bangladesh

percent of the population migrates each year, largely fuelled by two drivers: (1) people losing their village homes and livelihoods in disasters and (2) by people seeking employment opportunities created by the rapid growth of the garment industry [48]. According to the World Bank, the urban population in Bangladesh was 5.1 million people in 1971 (7.9 percent of the country's total population) and up to 62.8 million people by 2020 (38.1 percent of the country's total population). [41] [49] This rapid and uncontrolled urbanization has led to overpopulation and overstressed infrastructure systems and severe housing shortages with implications for living conditions and well-being (e.g., inadequate nutrition, lack of public health facilities, vulnerability to disasters, rising anti-social activities, rising unemployment, growing disparity of rural and urban income).

Wages in Bangladesh are some of the lowest in the world, job security is weak (as further demonstrated by the Covid pandemic), and while there has been safety progress, manufacturing workers are still exposed to unsafe work environments with a high incidence of work-related accidents and deaths, as demonstrated by the July 2021 fire in a juice factory that killed at least 52 people. [50] [51] [52] Furthermore, while there has been considerable attention and investment in fire safety of formal factories, informal and often home-based RMG enterprises in informal settlements that support international RMG sector supply chains do not benefit from these investments and workers continue to suffer from unsafe working conditions.

As a capital megacity, Dhaka attracts more migrants, resulting in extreme inequality within the urban periphery. [53] The city suffers from numerous transport problems. Citizens constantly complain about unbearable traffic jams where

vehicles remain stuck for several hours. Urban informal settlements represent the most affordable form of housing, and rural to urban migrants, both permanent and seasonal, tend to live in urban informal settlements or budget suburbs, as well as alongside the urban poor. [54] [55]

The number of informal settlements and the populations of informal settlements are not clear. There are discrepancies between data from the Bangladesh government and international datasets, with the local data far underestimating the number and population of informal settlements compared to international data. According to the Bangladesh Bureau of Statistics (BBS) there are approximately 14,000 'slums' in the cities and towns across the country where more than 2.2 million people live. [56] In contrast, UNICEF estimates the number of 'slum dwellers' to be approximately 20 million. [57] While this appears to relate to discrepancies in how informal settlements are referred to by local and international institutions, there may be political drivers behind the Bangladesh government indicating a lower number of informal settlements, in an effort to demonstrate positive development of the country.

Land ownership and tenure in Dhaka is complex and is often contested. Existing policies do not reflect the rapid change in the urban discourse of Bangladesh. Informal settlements are often located on land owned by government authorities such as the Bangladesh Telephone and Telegraph Board (T&T), the Ministry of Public Works and Housing, the Ministry of Science and Technology, City Corporations, and the Ministry of Railway. Eviction risks can be high and therefore it is difficult for residents and external stakeholders such as NGOs to invest in long-term development. [58] These settlements are often informally controlled and managed by local

'musclemen' and politicians. Jones explains *"the lived reality for millions of slum dwellers in Dhaka is one of deprivation and domination under an entrenched hierarchy of unequal power relations…in these circumstances, there is little prospect of residents achieving political freedom, economic empowerment, or social opportunities." (p.161)* [54]

Fire

The number of fires in Bangladesh has tripled over the past 22 years. [59] But the literature often points to the need for better data on fires. Although the Bangladesh Fire Service and Civil Defence (BFSCD) is required to keep a record of emergency incidents, damages and casualties, data are not always recorded properly. [60] For example, data on fire-related deaths and accidents in garment factories is unreliable and disputed. The Bangladesh Institute of Labour Studies calculated that 431 workers died in 14 major fire incidents in garment factories between 1990 and 2012, but the data covered only major fire incidents and likely understated the number of deaths. [61]

The BFSCD published yearly reports of fires on their website for the years 2015–2020. [62] The pattern/format of the data set from 2015-2019 remained unchanged. However, for 2020, BFSCD added new headings, e.g., training and inspections and removed other headings, e.g., no district-wide data. There was also a significant jump in the number of recorded injuries and deaths in 2020, suggesting there may have been discrepancies in data collection in previous years. The data on informal settlement fires from BFSCD suggests less than 260 fires have happened in informal settlements across Bangladesh each year between 2015 and 2020. A comparison between South Africa and Bangladesh in terms of number of fire incidents and casualties in

respective informal settlements suggests the BFSCD data grossly underestimates these values.

Massive fires in ready-made garment factories, informal settlements, high rise buildings, and refugee camps have made international headlines in recent years. While there are many extreme acute fire incidences, the reality is that Bangladesh's fire problem is chronic, and it is worsening. The number of fires in Bangladesh has tripled over the past 22 years. [59]

5.2 Pre-fire: Fire risk emergence

As discussed in Section 3, fire risk is created by interactions of hazards with vulnerabilities. The complex nature of fire risk emergence and its manifestation means there are many lenses through which it can be explored. This project aims to illustrate this complexity, but it is not possible to illustrate all the possible relationships succinctly. Therefore, the project team needed to choose specific themes to explore fire risk emergence. This choice was informed by the themes that emerged through interviews and reviewed literature, relevant to physical ignition risks and conditions that support fire spread, as well as an assessment of available evidence to explore emergent themes. Tenure (in) security, energy and informal economy were identified as the most evidence-full aspects of the systems map and therefore explored in greater detail.

5.2.1 Tenure and housing (in) security

Insecurity of housing and tenure of informal settlements is a key factor in fire risk emergence. Low-income urban residents in cities are unable to buy land via formal processes, or purchase housing or rent on legally developed land. Non formal tenure on land which is illegally occupied, developed, rented is therefore common and thus characterised by insecurity. [63]

It is recognised that there is a continuum of different types of land tenure arrangements: from customary and community tenure (i.e., traditional systems of land rights) to de facto tenure (i.e. as practised but not recognised in law) [64] Within informal settlements, different housing tenure types also exist: from owner occupied to rental properties owned by landlords who may live inside or outside the settlement. Whilst dwellings may be owned or rented out, the land they sit on may belong to others.

The key implications of land tenure insecurity for fire risk relate to service provision and housing quality. A lack of formal service provision (electricity, water, sanitation, transport) is often justified by the 'illegality' of informal settlements, where municipalities may feel less accountable to residents. [65] This can be linked to issues such as the inability of residents to exercise citizenship due to their tenure status (e.g., where voter registration may depend on a formal address) and lack of legal protection for residents in informal settlements. Deprivation of formal services by the state may be used to legitimise actions such as evictions for state or private sector development. This lack of services has a direct route to fire risk emergence via the development of informal services, namely electricity, which is a key fire hazard, and lack of adequate and accessible water supply, which can contribute to fire spread.

In terms of housing quality, residents may take their lack of tenure security into account when investing in labour and finance to improve dwellings and local services. There is evidence that housing tenure type influences these kinds of decisions. Burby et al (2003) talk of a tenure trap whereby tenants face a higher degree of vulnerability due to lower incomes, a potential lack of attachment to community, and

so lower motivation, ability and resources to invest in mitigation and preparedness measures. [66] The ever-present threat of eviction contributes to this insecurity, and disincentive to invest in risk reduction.

However, research has also shown that the longer households stay in informal settlements, the more social and political legitimacy may be leveraged [67], which may allow households to invest more in the quality of their structures and surroundings, demand services, and develop knowledge of local risks, thus reducing risks. On the other hand, McDermott et al [64] found that households that had been living in two settlements in Nairobi for longer periods were more likely to have experienced recent fire events, possibly attributed to older housing of degraded quality being more susceptible to fire hazards.

Arson as an eviction tool was mentioned by nearly all of the research participants across Dhaka, suspected to be used by landowners, both public and private [56] as a way of clearing land for development. While this was mentioned by a few interviewees from Cape Town, further evidence is needed to understand arson's prevalence in relation to eviction. There is little documentation and evidence on this, especially regarding perpetrators. [68] [69] [70] [71] [55] [72]. This also speaks to a general absence of formal investigation into fires in informal settlements, which perpetuates a lack of accountability, and impunity in cases of suspected arson. Arson and its root cause in market driven urban land development and land tenure insecurity of informal settlements requires further investigation.

Cape Town

Research into proximal design in South African informal settlements by Spinardi et. al. [36] explains that *"users of informal settlements*

are involved in ongoing projects of construction, improvement and adaptation" (p.533) and identifies the relationship between material choices and perceived permanence and security of tenure. For example, owner-occupied households may invest more in their physical environment than rental households due to differences in tenure and the associated cost-benefit ratio of physical upgrades, which may impact fire safety. Evidence of whether fire safety is a key performance objective of residents during construction, improvement and adaptation projects is lacking. However, other building performance objectives (e.g., dwelling size, thermal comfort and security) and (limited) access to materials resources do influence people's choices of construction materials and methods and sometimes are in conflict with fire safety (e.g. thermal insulation is often combustible). [73]

In Cape Town, newer settlements are at high risk of eviction, but long-standing informal settlements tend to be more secure. Despite a lack of legal recognition, there is pressure on the government from NGOs to provide administrative recognition of informal settlement dwellers. [74] This can enable informal settlement dwellers to provide proof of residence in order to access services such as financial institutions, schools, clinics and post offices, and recovery support from the government, including post-fire support. [75] Incremental upgrading policies are intended to support informal settlement dwellers to remain in situ, although access to these policy instruments is inconsistent based on a number of factors, including the physical and environmental nature of the land, and the politics of ownership and community. Implementation of these policy instruments is patchy.

The City of Cape Town does provide electricity, water,

sewerage, and waste collection to poorer households at a substantially subsidized rates. [76] This is a topic that links directly to the Constitution of South Africa highlights the right of all citizens to have access to basic levels of services. In 2000, the government announced its intention to provide free basic services to indigent households. While this was originally intended to exclude informal households, city governments, such as the City of Cape Town, eventually began to include basic service delivery to informal settlements. However, providing such services and infrastructure to informal settlements is made difficult by the absence of clear policies. It also puts local authorities in a position where they are to provide basic services but must not be seen to promote or legalise the permanent nature of informal settlements. This creates practical limitations which reduce the speed, scale, and coverage of policy implementation. Resident or landlord investment in informal settlement housing improvements using materials which make buildings more permanent, is also discouraged and runs the risk of demolition. [77] This temporary status can be seen to be part of a fire risk emergence complex: the right to basic service provision (including key fire risk determinants of water and electricity) is compromised, as well as dwelling construction using safer, non-combustible materials.

The provision of services also adds value to the informal (unregulated) rental and property housing market in Cape Town – dwellings with formal electrical connections (with meters) are worth more than dwellings with informal electrical connections, or no electricity. The electricity card[3] from the city can even act as a de facto title deed

3 A payment card which allows access to legal electricity connections for a specific dwelling.

for the transfer of a property with an electricity meter. [78]

Dhaka

Government policy states that only those with registered residency qualify for formal connections from the Dhaka Power Distribution Company and Dhaka Electric Supply Company, which excludes informal settlement residents. This results in informal energy use and its attendant risks (detailed in section 5.2.2), illustrating system linkages which create fire risk emergence routes.

While no informal settlements in Dhaka have secure tenure or can access formal services, there is a 2014 list from the Bangladesh Bureau of Statistics of recognized informal settlements (referred to as 'slums'). [56] Whether or not an informal settlement is recognized by the government impacts how non-governmental organizations engage with communities to provide poverty alleviation and development support. It is necessary to acknowledge the diversity of land and housing tenure status across and within informal settlements, and how diverse experiences may impact on fire risk emergence and safety in different ways.

Upgrading programs in informal settlements appear to be rare and non-governmental organizations expressed concerns in interviews about investing in the built environment since informal settlements can be evicted/destroyed at any time. Land and housing insecurity discourage dwelling improvements, thereby contributing to fire risk emergence.

5.2.2 Energy

Energy access and the ways energy is used are determinants of fire safety. [79] Energy poverty, inadequate access to energy infrastructure and reliance on unsafe and potentially hazardous forms of energy for daily activities such as cooking, heating, and

lighting, significantly increases fire risks and tends to be prevalent in informal settlements globally. [80] [54] [81]

Energy choices are influenced by affordability, convenience, accessibility and personal preferences. Women make most decisions on energy use and fuel choice in both electrified and unelectrified households in South Africa, regardless of the gender of the household head. [82] This contrasts with Bangladesh, where men tend to make energy-related decisions. [54] In both countries, women carry the greatest burden of energy choices, in terms of health, safety (including fire safety), and time taken for collecting and using different fuels. [54]

Several studies have found that low-income households in South Africa meet their energy needs with an energy stacking approach, meaning they utilize a mixture of electricity and other non-electric energy sources. [80] Paraffin is often used for cooking and spatial heating because it is inexpensive, accessible, reliable (i.e., not effected by power cuts or electrical trips) and versatile (paraffin only requires one appliance for cooking and spatial heating, whereas electricity users would require separate appliances to provide the same functions). [80] Electrification in Cape Town incurs capital expenses and recurrent costs associated with the use of electricity for cooking (households often cannot afford capital costs of appliances such as stoves; households prefer paraffin for cooking as a more cost-effective fuel). [34] Gas is also used by some people in informal settlements. [80] Candles are commonly used for lighting because they are inexpensive and reliable and serve as a backup during power cuts. Firewood and coal tend to be reserved for special occasions, or for spatial heating purposes. [80] Industrial activities such as mechanical repairs, construction work and industrial

informal enterprises (e.g., informal manufacturing and production businesses) may introduce other energy sources and appliances.

According to the *State of Energy in South African Cities 2020* report, 98% of households were electrified in Cape Town in 2017. [82] However, this report does not specify if electrification is through formal or informal connections. While the policy environment in South Africa supports electrification of informal settlements in general, barriers to formal electrification include land tenure and land suitability issues. [83] Furthermore, Cape Town's spatial layout is characterized by disparate, largely segregated informal settlements and urban nodes. The development of networked infrastructure to deliver basic services (e.g., electricity, water) to informal settlements is complicated and made more expensive by the need to traverse long distances. [84]

Most local governments, including the City of Cape Town, cannot keep up with the growing demand for service provision: there is limited institutional capacity to address service delivery backlogs, and a limited revenue base to fund basic services. [85] Households that do not have access to a formal connection, do not qualify for a subsidy, or require more electricity than the subsidy covers, are left to choose between the risky options of making informal connections to the electricity grid and using open flames for heating, cooking, and lighting. [36] [37] [86] Households without a formal electric meter provided by the city often access electricity with extension cords or makeshift wiring – also known as informal connections. 'Spaghetti wires' which criss-cross settlements over roofs and at ground level can cause fires and they may also prevent emergency vehicles from entering the settlement when a fire occurs. [73]

In Dhaka, almost all wealthy and middle-class households cook with

gas, but over 134 million people in Bangladesh (just over 17 percent of the population) do not have access to clean fuels for cooking (i.e. non-solid fuels such as natural gas and ethanol, or electric technologies). [54] [87] Informal settlement households cannot legally connect to town gas; but bottled gas systems are often beyond the financial reach of households. [54] This leaves informal settlement dwellers with little choice but to cook with firewood or LPG tanks, or to engage with 'mastaans' (local gangsters) to arrange basic service delivery, such as informal electrical connections or gas connections. [54] Informal gas and electricity supply lines spread across and between buildings, likened to spider webs. [88] The informal gas connections typically use plastic pipes, so leaks are possible, and the piping could melt if exposed to high heat. Gas connections and gas bottles expose residents and firefighters to significant life safety risks due to the high risk of explosions. [71] [89] [88]

Mastaans make financial arrangements with public officials and employees of utility service providers to connect the formal electricity grid via a pole in the centre of a settlement (a quasi-lawful connection), and then sell electricity to informal settlement residents at a high cost. Profits are shared between the mastaan and government officers. [54] [88] Residents are likely to be charged excessive fees for basic services delivered by mastaans. Korail residents, for example, may end up paying triple the rate per kWh compared to what middle-class customers pay in the formal economy. [54] Mastaans *"act on behalf of the powerful and politically connected…and mastaans are patronized and protected by political masters and the police." (p.160)* [54] Jones frames the energy system in Dhaka as an *"…unjust ecosystem for all residents of the city. Arrangements between informal energy providers*

and slum dwellers under the informal energy systems are part of the exploitive and oppressive social structure in Dhaka's slums… the absence of political voice for Dhaka's slum dwellers is widely recognized in the literature" (p.158) [54]

News correspondents from the Daily Star newspaper investigated informal delivery of gas, electricity, and water utilities to Korail informal settlement dwellers in 2017, and estimated there were at least 10,000 illegal gas connections, 15,000-20,000 illegal electricity connections, and 15,000-25,000 illegal water connections in Korail. [88] Despite evidence of illegal connections in informal settlements, the police have often denied their involvement in facilitating illegal connections. Utility companies have also said they do not provide any connections to informal settlements, and some have even denied the existence of informal connections. [88] The director of Titan Gas has acknowledged informal connections and said *"we launch drives against illegal gas connections there regularly. But things get back to square one after a few days."* [88]

5.2.3 Informal economy

Informal settlements can be vibrant locations for the informal economy, mirroring virtually every enterprise that exists in the formal sector. The spatial and social dynamics of the informal economy in informal settlements are fluid and constantly adapting to the needs of providers and consumers. Spatial layouts of informal settlements also evolve to meet the needs of residents, influencing which economic activities take place in and around the settlement. Unlike formal residential neighbourhoods, segregation between residential and commercial does not exist in informal settlements – conglomerations of residential dwellings and economic activities and enterprises co-exist. These

economic activities contribute to fire risk emergence by increasing fire hazards (increasing the number and type of ignition sources and higher/more diverse fuel loads), by complicating fire response (e.g., blocking egress/access pathways and roads) and increasing socio-economic vulnerabilities to fire (e.g., livelihoods affected). Through the literature review, we identified a large range of economic activities that take place in informal settlements in each city. We have filtered these and are showing economic activities with specific contributions to fire risk in **Figure 10**.

Some economic activities release flammable substances. Food vendors may store large amounts of fuel such as wood to cook food. Hazardous waste can be generated from mechanical workshops, oil and food waste from food services, medical waste, and paints and dyes from manufacturing. Fumes and smoke from enterprises which use fire to smoke and burn things or chemical processes can be dangerous. Electric short circuits and other electrical hazards can cause fires. Welding and other types of hot work present ignition hazards.

Lack of infrastructure and services pose a range of hazards related to problems of sewage, waste management, lack of water and sanitation, poor ventilation and lighting, and ergonomic risks, which may contribute to the emergence of fire risks.

Most entrepreneurs and workers participating in the informal economy are thought to be barely able to make ends meet, as they are working to generate necessary income. Many of the urban poor lack education and skills which are necessary for most jobs in the formal sector and are therefore forced to conduct informal economic activities, many of which choose self-employment. The prominent characteristics of the informal economy are ease of entry, lack of formal law, lower skill requirements, out of tax regulation, and social and economic insecurity. Seasonal migration contributes to high population densities during certain times of year in both Dhaka and Cape Town.

Enterprises are often small-scale and are driven by individual resources, such as personal dwelling. Women are a dominant workforce in home-based
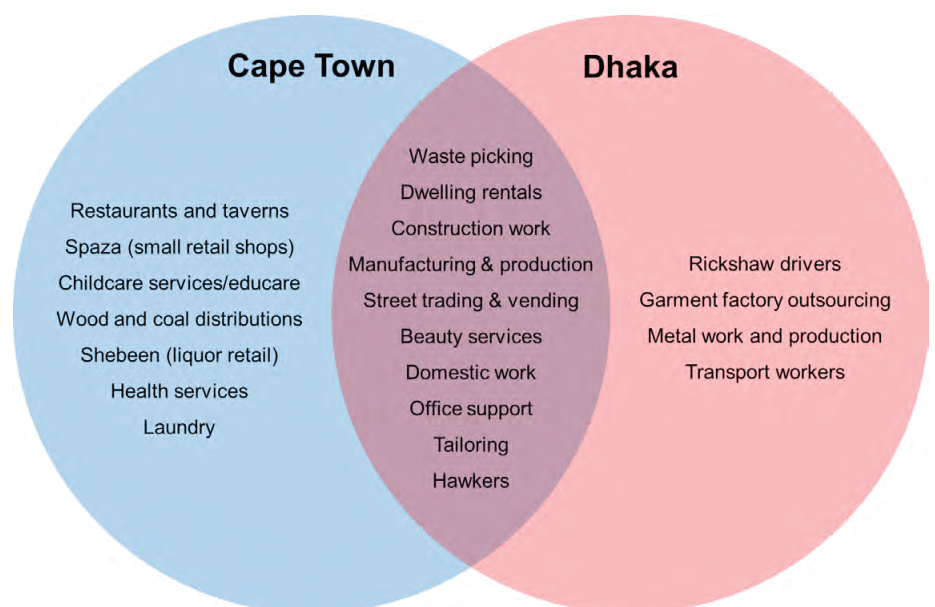

Figure 10: Economic activities within informal settlements in Cape Town and Dhaka, as identified in the literature

businesses because it allows them the opportunity to contribute to household income while remaining household caretakers – 60 percent of informal enterprises in South Africa are home-based. Home-based enterprises are relatively cheap to set up and require low overheads, thus they are a key component of the informal economy within the settlement setting.

In Cape Town's informal settlements, in contrast to high street businesses, micro-enterprises within residential areas cater to the immediate needs of local consumers in the form of food, household necessities, personal services, leisure and socialization activities. The most commonly reported micro-enterprises are liquor retail and grocery (spaza) shops, which sell daily necessities which are mostly pre-packaged and sold in small quantities, house shops and childcare centres. Other businesses and services include renting dwellings, manufacturing, hair salons, street traders, and traditional healers.

In Dhaka, economic activities in informal settlements do not only cater to the needs of locals but they also tend to support the city more widely. Street vending and rickshaw pulling is common, along with small manufacturing enterprises (many of which are home-based) supporting the Ready-Made Garment industry. It is important to acknowledge the positive role residents have in keeping Dhaka running. *"Most middle-class Dhaka residents engage slum dwellers in some form of employment ranging from use of rickshaws to employment of home servants and private drivers."* (p.154) [54]

Despite clear linkages between the informal economy and fire risk emergence in Dhaka and Cape Town based on a review of these economic activities, there is little discourse on this relationship. Interviewees were able to discuss the relationship between economic activities and fire risk when prompted, but they seldom introduced this topic themselves.

Some literature on fire risk in Dhaka refers to Old Dhaka, the historic old city, which is a formal residential area of the city but with significant non-compliances, often in relation to informal economic activities. This illustrates that the informal economy is not limited to informal settlements and there can be informal economic activities carried out in formal areas, as well as formal economic activities carried out in informal areas of the city, reinforcing the narrative that (in)formality is a spectrum; it is not absolute.

Old Dhaka is particularly vulnerable to fire due to a range of factors including high population density, narrow roads, flammable building materials, electricity short circuits, gas leaks, stoves, outdated water supply systems, unplanned construction, chemical and hazardous materials workshops in residential buildings, lack of preparedness and coping capacity to manage fires, and limited knowledge of fire-fighting techniques. [90]

An estimated 80% of residential houses in Old Dhaka have a factory or warehouse on the ground floor, with dwelling areas on other floors. Most of these warehouses or factories contain chemicals or plastic materials. In 2019, a road traffic accident caused a gas cylinder to explode, and the fire spread to nearby residential buildings used to store chemicals. This fire killed at least 80 people and left more than 50 people injured. A fire in a 5-storey residential block in Nimtoli, in Old Dhaka, in 2010, which began in a warehouse on the ground floor of the building, killed more than 100 people, and is widely cited as an example of the risks posed by inadequate high-rise structures. The building did not follow code regulations: it had no fire escape; windows had metal grills with no openings; and chemicals were stored on the ground floor. Firefighters struggled to reach the fire due to heavy traffic and narrow lanes. [61] [90] [91]

5.3 During fire: Fire Incident

The fire risk complex adaptive systems framework (**Figure 6**) includes the period during a fire incident, providing an opportunity for specific fire dynamics to be explored, as well as human and institutional responses to fire. [73] [12] [92]

During a fire, the high risk of fire spread in informal settlements is largely driven by materiality and spatial arrangements of the built environment, i.e., combustible materials of construction, high dwelling densities, inhabitants storing materials in and around homes, poor construction materials and techniques, and the influence of the natural environment on fire behaviour, e.g., topography, wind, moisture conditions, and ambient conditions.

Behaviour of large outdoor fires, or conflagrations *"can become large, behaving in ways more akin to that of wild-land fires (due to the distributed fuel load, accompanied by very permeable structures), rather than typical structural compartment fires."* (p.344) [93] Walls et al [93] summarize the mechanisms of fire spread between dwellings in the illustration shown in **Figure 11**. No similar technical work has been carried out in Dhaka.

The risk of ignition and fire spread in informal settlements is largely a function of the limited choices poor households have regarding where and how to live: e.g., daily practices for cooking, lighting and heating often include the use of open flames; a combination of combustible building materials, high density and unplanned settlement layouts with minimal firebreaks allows fire spread between dwellings. [36] [73] [94]

Branding/spotting: Flaming brands can be carried long distances and land on ignitable items, causing new spot fires.

Min. 2-3m to avoid flame impingement (potentially further in wind)

Min. 3-5m to avoid ignition by radiation (potentially further in wind)

Flame impingement

Radiation

Opening size influences the size of flames emitted.

Small holes in walls, or unsealed spaces between walls and roofs, can easily allow flames to ignite items within the dwelling.

Doors and windows will always be weaker points for ignition resistance, even if a home is fireproofed.

Products such as plastics (for waterproofing) or cardboard can easily be ignited by radiation over a distance.

Timber, plants, rubbish and stored materials between dwellings form fire bridges.
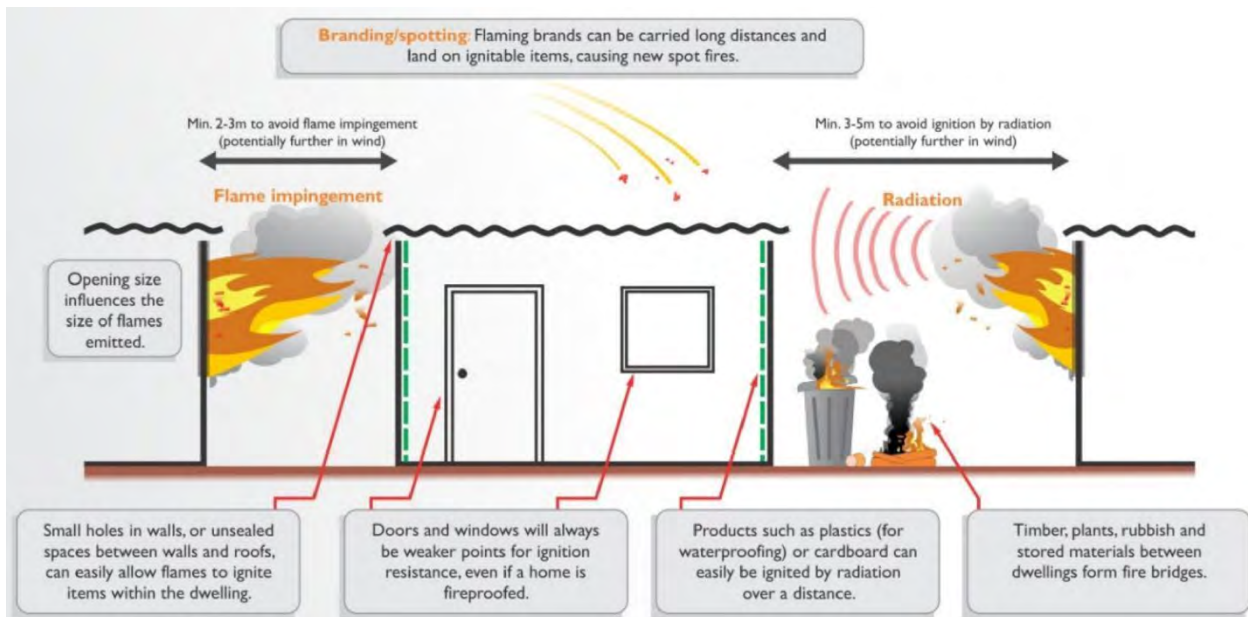
Figure 11: Illustration of how dwellings catch fire from flame impingement (left), radiation (right) and ember attack (top); extracted from [94]

Once a fire ignites, **fire detection** could be via automatic means (e.g., smoke or heat detector), where available and installed/maintained properly. However, most fires are detected by people through visual, smell or audio cues. People shouting to warn others of the fire is the most common method of **fire warning** in informal settlements.

Human responses during informal settlement fires are not well understood. The best evidence related to human responses during informal settlement fires in South Africa comes from Quiroz's et al [95] analysis of fire spread, human behaviour, and firefighters' response and operations during a fire incident. Common resident behaviours observed were information seeking, firefighting attempts, valuables gathering and re-entry behaviour. *"In the beginning, once they [residents] discovered the fire, the response of the resident was mainly focused on firefighting actions. Then, when they realized that it is not possible to control the fire, the efforts changed to gathering their valuables, this action involves leaving and re-entering* the dwelling. After the fire was extinguished, the main actions were looking after their valuables and cleaning the debris." (p.11) [92] Some actions observed in the video indicate residents had to make difficult risk trade-offs during the incident, e.g., man on a roof pouring water onto the fire putting him at risk of injury or even death, suggesting he accepted the risk of injury over the risk of property loss. In South Africa, *"it is known that many fires are never reported to the fire department because they are managed by the community, and further firefighting support is not needed". (p.81)* [40] Further research is needed to *"investigate methods of firefighting used by communities and informal training that takes place between community members with regards to fire response". (p.127)* [73] Despite clear evidence that informal settlement residents play a central role in fire response and recovery, their diverse involvement and perspectives are not discussed much in the literature. No literature has been identified which discusses human responses during informal settlement fires in

Bangladesh. However, interviewees acknowledged the central role informal settlement dwellers have during fire response.

Fire services response to informal settlement fires is often hampered by delayed notification, traffic, challenges finding the location of the fire, poor access due to a lack of road infrastructure and low hanging electrical fires, limited or no accessible water infrastructure to support firefighting efforts, and in some cases, social tension with residents. For example, crowding around fires is common in Dhaka, which may motivate police involvement for crowd control. Negative interactions between residents and the fire services seem to be limited to verbal interactions in Dhaka, whereas in Cape Town this sometimes manifests in conflict and even physical violence, such as firefighters having rocks or bricks thrown at them upon arrival to a fire scene. [73] [96] Delayed response of the fire services and the wider political context likely contribute to these social tensions. [73] Further research is

needed to explore this narrative from the perspective of informal settlement residents who have not been engaged with/ represented in research on this topic to date.

5.4 Post-fire: Fire Consequences

The following five types of direct fire consequences were most often identified through the literature review and interviews [36]:

- Fatalities
- Injuries
- Material/property loss
- Displacement & homelessness
- Damage to physical & social infrastructure

Trauma & other mental health impacts (personal and communal), disruption to livelihoods, fractured social support networks, compromised access to services (e.g., lack of access to critical medication), and consequences to the environment (e.g., pollution to air, water, and soil) have also been identified as consequences from fires in informal settlements. [36]

There is a lack of reliable data on fire incidents, fatalities, injuries, impacts and costs from informal settlements globally, and locally in Cape Town and Dhaka (see Section 5.1). [1] Comparing fire consequences between cities is further complicated due to incompleteness, poor quality and inconsistency of fire incidence data and challenges with data collection, management, and reporting. [1] While government stakeholders, such as the fire services in Cape Town, may estimate the number of dwellings affected by a fire and record injuries and fatalities immediately after completing firefighting operations, environmental consequences and indirect or cascading consequences are rarely reported or traced following the immediate period of a fire. [94]

For IS fires it must be understood that in some instances indirect impacts on livelihoods and life safety may be greater than direct impacts, hence the protection of homes is important for long-term sustainable development. Immediate needs of fire survivors, such as food, shelter, and water need to be met to maintain life safety. Longer term, negative impacts to livelihoods and development are likely if, for example, people are injured or killed in the fire (e.g., parent unable to work), businesses are disrupted, community facilities are destroyed limiting access to childcare or education, or people need to take out loans to rebuild homes (increasing indebtedness).

Fatalities and injuries relate to both physiological and psychological vulnerabilities. Persons requiring assistance to evacuate, such as children, elderly persons, and persons with disabilities are particularly vulnerable during fires. [75] People with other health conditions, such as respiratory diseases, may have a lower tolerance when exposed to the effects of fire and smoke. Social determinants of health and access to healthcare are dynamic pressures that impact people's health pre-fire, as well as people's experiences post-fire if injured. Access to first aid and ambulatory services, as well as appropriate burn-care units can directly impact injured persons' health. Fire can cause trauma and other mental health impacts, however, discourse on this issue appears to be limited in relation to fires in informal settlements. [75] [97] [98]

When there are fatalities, surviving members of a household may experience significant socioeconomic impacts and setbacks, e.g., from funeral costs, loss of caregivers, loss of household livelihoods. Fire may cause children to miss school and adults to miss work, thereby undermining not only short-term needs such as livelihoods but also long-term development goals. Loss of property can impact businesses and livelihoods, meaning residents with home-based enterprises may experience compounded consequences from the loss of their home and business/livelihood if their dwelling is damaged or destroyed. Research into how households cope (or don't cope) with the direct and indirect consequences of fire is needed.

Property loss can lead to people sleeping in the open or in other precarious situations, especially if they are prevented or delayed from rebuilding. As discussed in Section 5.2, arson is sometimes used as an eviction tool for land clearance in Dhaka, which could lead to permanent displacement of informal settlement dwellers. Accidental fires may also trigger displacement if the state or private landowners prevent reconstruction.

Media coverage and literature on fires in informal settlements in Cape Town and Dhaka is typically limited to reporting the details of the fire and its direct consequences immediately after large fire incidents. Media occasionally covers the fire recovery process when external actors such as government agencies or large non-governmental organizations, have made commitments to support recovery. Recovery can get very political and most of these media reports highlight points of contention between stakeholders and misalignments of expectations and reality through recovery. Nonetheless, most people affected by an informal settlement fire do not receive external aid, especially if the fire is relatively small and not covered by media sources.

External aid post-fire may help to relieve suffering of fire victims and may support recovery. However,

it is also important to note that external aid may lead to externally controlled recovery, often in the name of building back better, which may compromise the agency of people directly affected by the fire and hamper or even prevent their recovery. [99] [100]

Applying engineered top-down solutions that are bureaucratic and structured from an outside perspective is likely to fail because these solutions are seldom in line with hyper adaptive reality on the ground. [99] Fire incidences and their cascading effects happen quickly, and peoples' needs are immediate. There is not enough time to strategically plan how to *build back better* after an incident without causing socioeconomic consequences related to associated delays in recovery. [99] [77] This demonstrates the need for recovery planning, but there is profound psychological proof that we don't like to think about what could go wrong because we believe that it won't happen to us, which limits recovery preparation efforts. [99] This is despite fires being recurring incidences, even in the same settlement.

The recovery process after a fire is always difficult but in addition to having insecure tenure, limited resources and support, informal settlement residents affected by fire must often cope with other incidents that cause further destruction, undermining and delaying recovery efforts. As an 'extensive disaster risk'[4], urban fire is a recurring hazard [1].

Figure 12 shows some of the fire incidents that occurred in Imizamo Yethu informal settlement between March 2017 and September 2020 which complicated recovery efforts from the large fire previously discussed. Other incidents, such as a June 2017 storm with high winds that blew down many dwellings further undermined recovery. One article reported that some displaced families from the March 2017 fire were affected again by the April 2017 fire. The increasing number of fire victims makes it difficult for stakeholders to balance long-term (and often overlapping) recovery efforts with immediate disaster relief needs. The other fires that occurred in Imizamo Yethu after the March 2017 fire created/exacerbated tensions between providing immediate relief to fire victims, self-recovery efforts, and delivering on build back better commitments for longer-term fire mitigation strategies.

4 According to the United Nations Office for Disaster Risk Reduction (UNDRR), an extensive disaster risk refers to "repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts" [1]

Recovery after a fire is a dynamic process where aims to build back better are often not achievable given limited sources and reconstruction may result with poorer quality homes, especially where materials are re-used post-fire, and there is less access to basic services such as water, sanitation, and energy infrastructure. This means communities are often more susceptible to fire and other shocks and stresses after they have experienced a fire, perpetuating a vicious cycle of hazard exposure and vulnerability.

Preparing for recovery is needed, by developing skills and systems that enable society to be good at adapting to and dealing with crises. [99] This focus on building social resilience of the community, will enable them to cope with fire and other shocks and stresses. [101]

The response and recovery to the March 2017 Imizamo Yethu informal settlement fire is complex, contentious, and has engaged many stakeholders over the course of months and years. While some residents agreed with the need to rebuild with improved infrastructure and fire mitigation, the city's proposal to 'super block' the
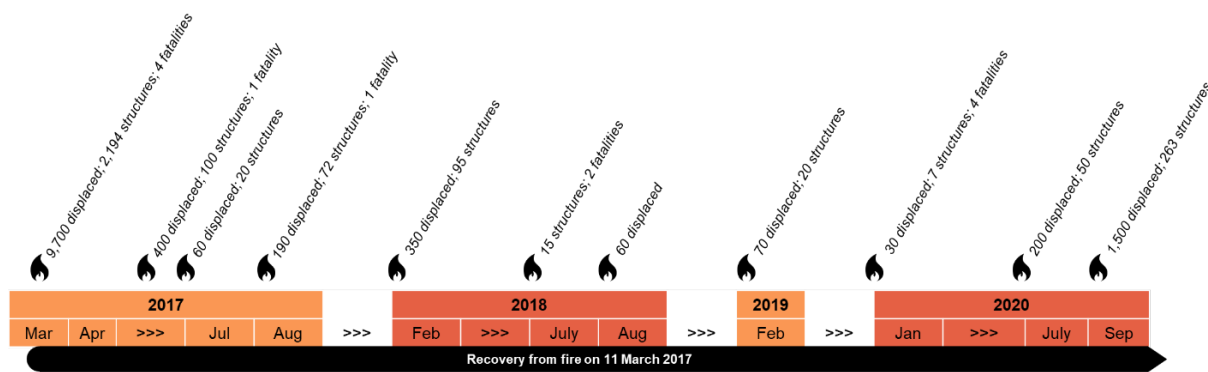

Figure 12: Timeline showing some of the fires in Imizamo Yethu informal settlement from March 2017 through September 2020

fire affected areas in an effort to *build back better* was strongly opposed by many residents. Based on interviews and review of media reports, it is clear self-recovery efforts post-fire were hampered by this longer-term initiative. People tried to rebuild on the fire affected area and the city sent the anti-land invasion unit to demolish the shacks and obtained a court interdict to disallow people from building in the area. [102] It is also clear that residents' efforts to self-recover undermined the city's plans for super-blocking, demonstrating the interdependencies and conflicts between top down and bottom up recovery efforts.

Globally, most people affected by disasters must rebuild their homes without external aid – they 'self-recover'. Research done by humanitarian agencies on self-recovery shows that homes often incorporate the same vulnerabilities as before a disaster, and there is a need to understand and provide appropriate support to such efforts. [103] However, there is limited evidence on how people affected by fires go about this and cope with diverse consequences that affect their household and community. During interviews, it was highlighted that there are market driven solutions to support recovery, such as a booming ready-made structure business. It was observed that renter occupied dwellings tend to be rebuilt more quickly than owner occupied dwellings because they are financial investments by landlords, and they want to be able to collect rent as quickly as possible after a fire.

Further research is needed to understand interactions and relationships between stakeholders post-fire, especially the effect (positive/negative) of external actors' post-fire; refer to Section 5.6

for further insights revealed from this study.

5.5 Mapping fire risk emergence

In this section, research findings are discussed and illustrated through a visual representation of fire risk emergence, manifestation, and its resulting consequences, via a systems map. This approach is reflective of the complex and multifaceted nature of fire risk. The mapping is based on generalized findings from the two cities – Cape Town and Dhaka – to highlight shared complexities with fire in informal settlements, despite differences between contexts.

The clusters in the full systems map align to the key tenets of the fire risk complex adaptive systems framework, including the timeline of *pre-fire*, *during fire*, and *post-fire*, as shown in **Figure 13**. While the systems map can be interacted with in several different ways, it is suggested to start at fire risk and then review the factors which contribute to fire risk (ignition risks, conditions that support fire spread, physiological & psychological vulnerabilities) and how they emerge from the interactions between root causes (shown in black), dynamic pressures (shown in grey), fire hazards (shown in orange), and vulnerabilities (shown in red); see **Figure 14** and **Figure 15**.

Then it is suggested to review the *during fire* cluster to explore how fire risk manifests during an actual fire incident, and to consider human responses to fire. Next, we suggest moving onto the *after-fire* cluster to learn about the direct and indirect consequences of fire, including how consequences cascade and finally how fire consequences and even recovery efforts can create feedback loops to contribute to further fire risk emergence.

5.6 Fire safety in a complex adaptive system

Fire safety can be considered as *"the set of practices to prevent or avert occurrence of fire and*

manage growth and effects of accidental or intentional fires while keeping resulting losses to an acceptable level." (p.2) [104] Urban fire safety typically includes regulatory system development, implementation and enforcement, fire services response infrastructure and capacities, and public education (i.e., prescriptive education to the public). This top-down command and control approach to fire safety has contributed to safer outcomes in the US, UK, Australia, and many other high-income countries.

However, fire safety in informal settlements, especially within the context of LMICs, can be viewed as more of a hybrid system, comprising engineered fire safety subsystems extended from formal areas and ad hoc fire safety subsystems which emerge and adapt to a context shaped by marginalisation and lack of resources. There is no centralized authority – no clear stakeholder or group with designated responsibility for fire safety. Instead, the system constitutes self-organized actors who have various roles before, during, and after a fire, which may overlap or interact, but without much coordination. This lack of designated roles and responsibilities is reflected in the notable lack of fire safety in informal settlements discourse from disaster risk reduction, urban resilience, and urban development discourses in both Cape Town and Dhaka, and more widely. [105] [55] [74] In this context, fire safety in informal settlements becomes even more of a neglected issue. More generally, it was highlighted that disaster risk reduction discourse is reactionary, and not focused on addressing the root causes and dynamic pressures leading to the emergence of vulnerabilities and hazards through development. [106] Closer collaboration between development and disaster risk reduction actors is needed not
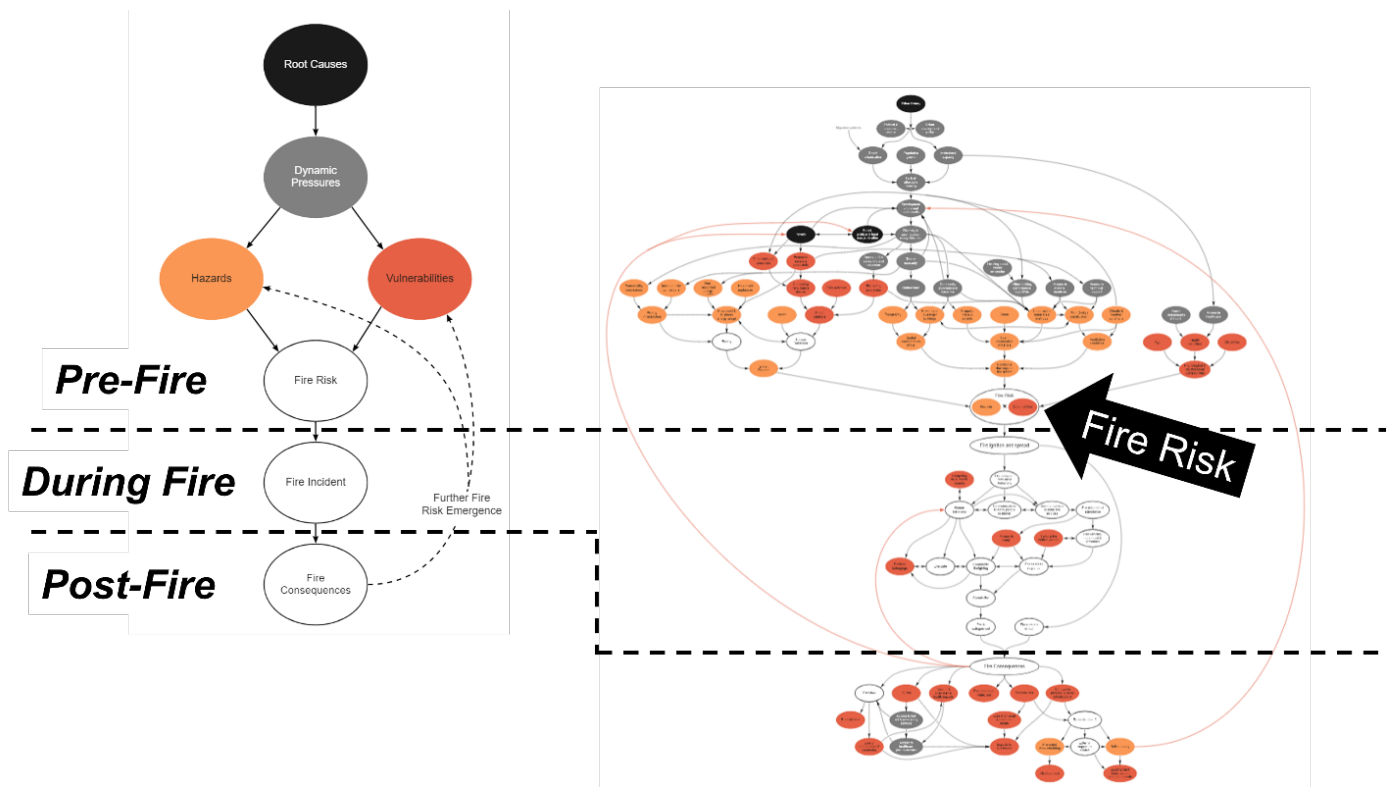
Figure 13: Alignment between fire risk complex adaptive systems framework and full systems map

only to understand urban fire management, but urban risk management (multi-hazard). [106]

The following sections discuss current fire safety systems in Cape Town and Dhaka.

Cape Town

The Cape Town government, including the fire services and disaster management agencies, takes a command-and-control approach to managing fire safety of formal areas, primarily through regulations and emergency response systems. As evidenced by media coverage, city supported research initiatives, and through discussion in this project's interviews, it is clear the city acknowledges the frequency and severity of informal settlement fires and the need to complement the formal fire safety system with localized, community-based fire safety systems. Various government actors, academic institutions, non-governmental organizations, and private sector

organizations have invested resources into fire safety in informal settlements, including research on fire behaviour and the development of technical interventions, such as smoke/fire alarms, application of intumescent paint, distribution of water buckets, and installation of passive fire protection systems (e.g., boarding systems). [94] [107] However, these top-down interventions often lack community participation, and ownership of these fire safety interventions is rarely transferred to communities. As referenced in Section 5.3, local community-led fire safety practices are rarely well understood, supported, or considered in the design of top-down fire safety systems; more research is needed in this area. Based on project stakeholder mapping efforts and insights from literature and interviewees, **Figure 16** indicates some of the stakeholders which have engaged in informal settlements in the name of fire safety before, during, or after a fire incident in informal

settlements in Cape Town. The subsequent text shares deeper insights into stakeholder roles and interactions, based on information shared by interviewees, a desktop review of relevant literature and media reports on individual fire incidents and stories of post-fire recovery.

Several interviewees identified that many informal settlement residents have a high level of awareness regarding fire risk. [107] They suggested that limited resources and choices for where and how to live may prevent residents from prioritizing fire safety over competing hazards and priorities. [108] [84] [109] [107] [36] [110] Simultaneously, there was acknowledgement that many people living in informal settlements do have strategies to reduce fire risk and respond to incidents, e.g., weakened corner of a dwelling to enable quick escape [98] [111] [112], and that communities do often respond effectively to fires, e.g., as indicated by fires being

Legend

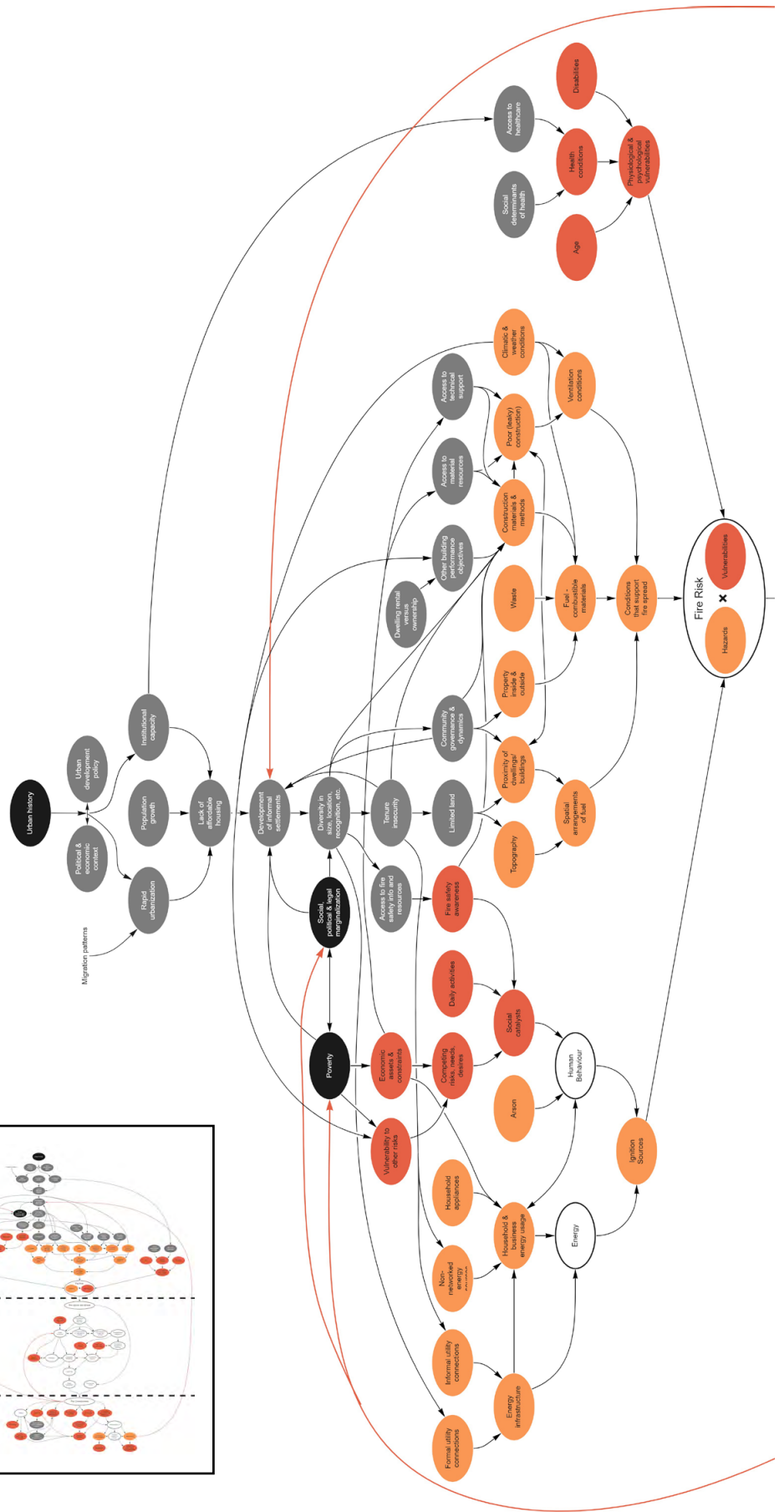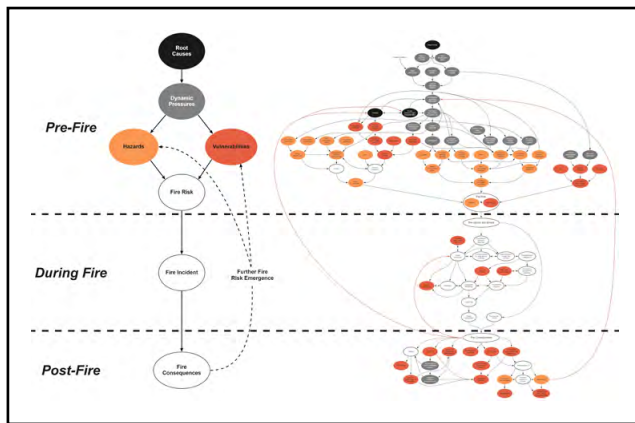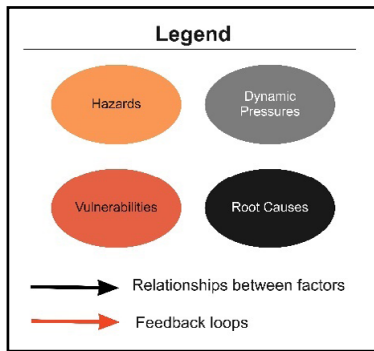Hazards
Dynamic Pressures
Vulnerabilities
Root Causes

Relationships between factors
Feedback loops

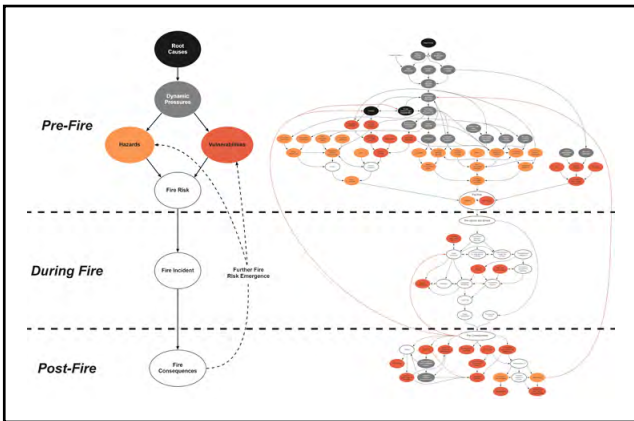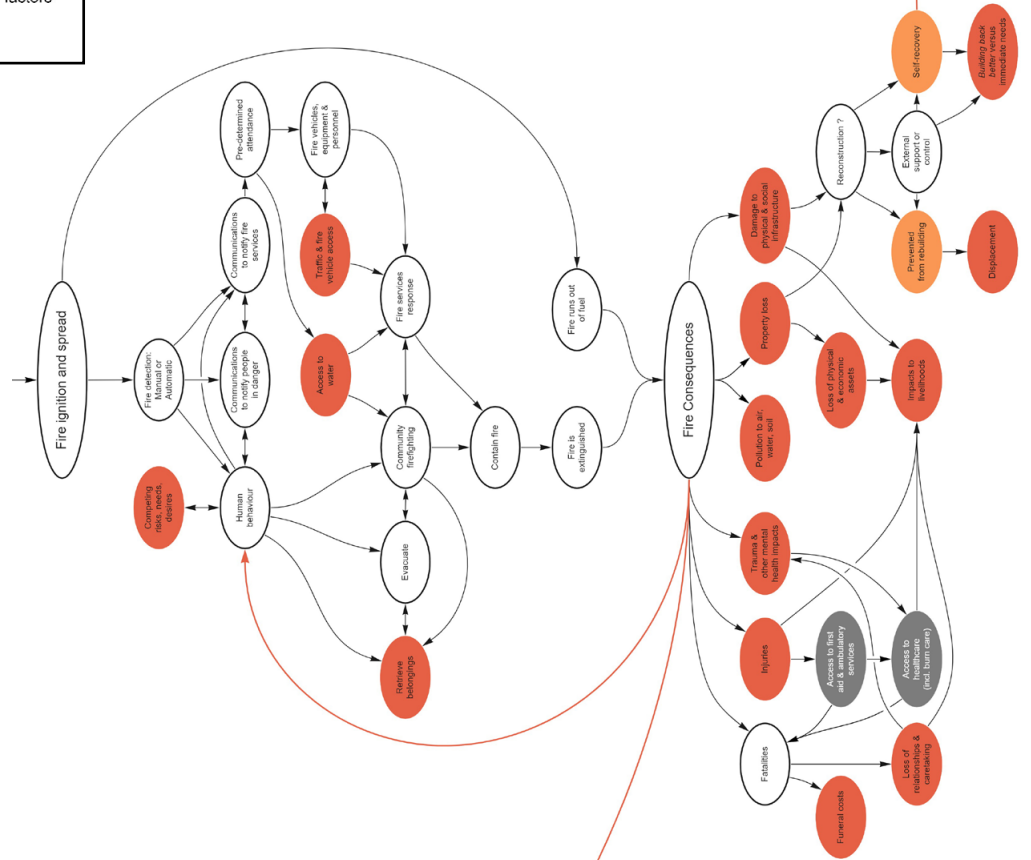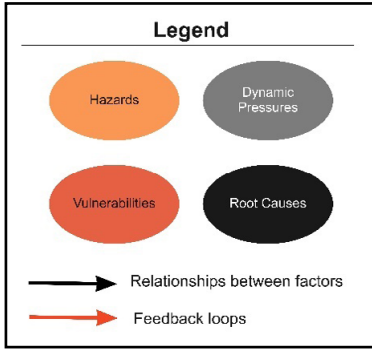Figure 14: Fire risk emergence in informal settlements (top of diagram)

Figure 15: Fire risk emergence in informal settlements (bottom of diagram)

Figure 16: Stakeholders who may support fire safety before, during, and after a fire incident in an informal settlement in Cape Town

extinguished by the time the fire services arrive. [110] As discussed above, further research is needed to identify and understand local knowledges and community-led fire safety practices *pre-fire*, *during a fire*, and *post-fire*. Additionally, the roles of community-based organizations (CBOs), including faith-based organizations, need to be better understood. Interviewees identified these groups as playing a significant role in communities, especially post-fire in providing relief to affected residents and to support recovery efforts. [109] [108]

The *'pre-fire'* period represents non-emergency environments when informal settlement residents are going about their daily lives uninterrupted by a fire incident (although they may be affected by other hazards). This time refers to the emergence of fire risk, as discussed in Section 5.2. During these non-emergency times NGOs often engage with communities to provide social services, support incremental upgrading of dwellings, help facilitate re-

blocking projects[5], and support community capacity building. Through policy frameworks such as the national Upgrading Informal Settlements Programme (UISP) and wider constitutional commitments to housing and basic service delivery, the Department of Human Settlements, municipal leaders, and state-led infrastructure providers such as Eskom, also engage with NGOs and communities to enable service delivery, incremental upgrading, and re-blocking projects, albeit the speed and scale of these projects are often limited by policy stipulations, bureaucracy, limited resources, and in some cases, political tensions between stakeholders. [74] [109] [100] [78]

Seldom are these types of projects carried out in the name

of fire safety, but the risk of fire is often identified as a key issue facing communities and some fire safety interventions may be included, such as the distribution of fire extinguishers or fire blankets. Through review of media coverage, NGO reports, and interviews, it has been identified that fire safety is often communicated as an added benefit of NGO and state efforts to improve living conditions in informal settlements. For example, reducing the risk of fire spread is often advertised as a benefit of re-blocking projects. However, while common features of re-blocking projects like reducing the density of dwellings and improving access pathways can improve fire safety, these projects seldom consider specific fire risk factors and fire spread mechanisms. Technical input from fire safety professionals is rarely brought into these development processes, leading to missed opportunities for fire risk reduction. [74] In the worst of cases, this leads to increased fire risks and decreased fire

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5 Re-blocking involves the realignment of structures in an informal settlement to enable basic services to be delivered and to create more usable communal spaces and improve safety. The process of re-blocking can be a valuable collaborative planning tool to build grassroots capacity. [106]

safety, e.g., when interventions are inappropriately advertised as significantly improving fire safety despite their limited safety benefits (e.g., intumescent paint, boarding systems, metal sheeting systems). This can impact residents' risk perception, fire response plans and actions. One interviewee identified that many development practitioners are keen to engage with technical fire safety specialists, but these specialists lack contextual knowledge and methods to provide technical support outside formal environments, limiting the value of their contributions in informal settlement contexts and thereby reducing the likelihood that development practitioners will reach out for their support. [74] It was identified that capacity building of technical specialists to consider the wider political, social, and economic contexts is needed so that they can work as effective partners in complex low resource settings like informal settlements. [74]

The *'during fire'* period represents the time during a fire incident. As discussed in Section 5.3, the primary stakeholders involved in fire response are the people living in the area affected by the fire and the fire services. In some situations, the fire services may ask for police escort or support during a fire incident, in response to or in anticipation of negative interactions with community members. [110]

The *'post-fire'* period represents the time immediately after a fire incident as well as the recovery period. As indicated in Figure 16, many stakeholder groups may get involved with fire relief or recovery.

The Cape Town Fire & Rescue Services respond to every fire that is called in and document direct losses (i.e., injuries, deaths on scene, estimate of dwellings lost) post-fire. [110] Disaster Risk Management

Centre[6] may then carry out a more detailed damage assessments and municipal departments, including ward councillors, may get involved to coordinate relief and recovery. [113] If more than 10 people are affected by a fire, Disaster Risk Management may contact the South African Social Security Agency, which can distribute items such as mattresses, food, dignity packs and possibly a Social Relief Grant of Distress. [113] The Disaster Risk Management Centre may also contact the following municipal departments, depending on damage to infrastructure: water and sanitation, electricity distribution, solid waste (to clear debris). [113] [78] [100] [110] [114] [75] [111]

Media reports indicate that neighbouring communities, especially people living in neighbourhoods with formal dwellings, and NGOs, often provide relief immediately after larger fire incidents. These groups may register fire victims and distribute relief such as food, water, clothing, blankets, and vanity packs. Some NGOs may even provide emergency housing materials and construction support, but the impact of these efforts is often limited by a lack of communication and coordination among NGOs, communities, other non-state and state actors.

Until 2020, the City of Cape Town would often provide emergency shelter kits after a fire, often even for incidents that only affected a few households. However, in 2020, the city announced that

6 "The Disaster Risk Management Centre (DRMC) identifies, prevents or reduces the occurrence of disasters and softens the impact of those that cannot be prevented." They "also facilitate the coordination, integration and efficiency of multiple emergency services and other essential services to ensure that these organisations work together, both pro-actively through risk reduction, planning and preparedness; and reactively through response, relief, recovery and rehabilitation." [118]

national budget cuts left *"no money to continue this extra service that goes beyond our core basic services mandate as a municipality"*. [115] Now fire kits can only be issued if a disaster is declared and provincial or national funding can be accessed to support disaster recovery, most commonly accessed by the Western Cape Department of Human Settlements via housing grants. [113] While there is a relationship between the scale of damage from a fire (i.e., number of dwellings affected) and disaster recovery support provided, there are no clear triggers in policy instruments nor standard operating procedures to guide decision makers on when this type of support should be provided. Furthermore, it is not clear if a disaster needs to be declared for the government to provide other forms of support, such as restoring infrastructure damaged during a fire incident.

In a few instances, the government takes on an active role in coordinating reconstruction post-fire in the name of *building back better* (and safer). The most recent large-scale example of government-controlled or managed fire recovery was in response to the 2017 Imizamo Yethu fire. As discussed in Section 5.4, stakeholder relationships were often stressed through this process, especially in the immediate 12 months post-fire, and a lack of alignment in priorities and practical plans between stakeholders significantly affected progress by communities in their own self-recovery and limited the success of top-down redevelopment plans. There appears to be a general lack of knowledge and respect for communities' capacities and agency in reconstruction post-fire, as well as a lack of understanding of the importance of households' timely recovery to enable them to secure their basic needs and livelihoods. Well intended plans for building back better do not seem

to grapple with the lived realities of informal settlement residents and therefore may be resisted, ignored, and subverted in practice. [36]

While it was acknowledged by several interviewees that most fire victims recover on their own (self-recover), little is understood about these processes and outcomes. Further research is needed in this area.

Finally, while most fire safety efforts focus on managing physical risks, further work is needed to explore other avenues of protection beyond addressing physical risk factors. For example, a social enterprise has been selling a fire micro-insurance product to informal settlement residents in Cape Town in recent years as a way to help reduce households' socioeconomic risks in the face of fire. This insurance product is distributed together with a networked fire detection/alert device and in partnership with a private South African insurance firm. Within a settlement, there are often households who can and will afford it, and others who can't and won't. [99]

Dhaka

In Dhaka, fire safety also follows a command-and-control approach. There is a lack of institutional capacity and infrastructure to manage rapid urban expansion, limit fire risk emergence, and respond to fire incidents. There is much concern about building standards and vulnerability in such buildings, particularly fire risk, relating to widespread lack of adherence to the Bangladesh National Building Code (BNBC), and the absence and/or inadequacy of firefighting and evacuation systems. While there have been significant investments in factory fire safety and related regulatory development and enforcement since 2013 (see Section 5.1.2), further improvements are needed in this sector, and these investments seem to have had limited benefits to fire safety in other sectors and for residential areas.

Over the past decade, fire incidents in RMG factories (industrial sector), high rise buildings, and more recently in refugee camps in Cox's Bazar have raised attention in Bangladesh. [105] [55] However, attention and investments in fire safety rarely target informal settlements. [105] [55]

While the fire problem in informal settlements is acknowledged by the media, government and non-government stakeholders, there is very little research, writing and discourse on this topic in Dhaka. For several stakeholders interviewed, this engagement was the first time they had considered the issue. Except for a few community-based fire safety pilot projects and limited fire response training provided to residents from the Bangladesh Fire Services & Civil Defence (FSCD), fire safety in informal settlements does not appear to be discussed nor invested in by disaster risk reduction or development actors.

Based on project stakeholder mapping efforts, and insights from literature and interviewees, **Figure 17** shows which stakeholders may support fire safety before, during, or after a fire incident in an informal settlement in Dhaka.

Communities living in informal settlements and CBOs that support them on a daily basis are best positioned to understand fire risk and to develop locally appropriate fire safety practices. These stakeholders are clearly involved in fire safety before, during and after a fire incident. However, very little is understood about these knowledges and practices in Dhaka and further research is needed, such as community-based surveys of perceptions and experiences related to fire, and existing fire safety practices.
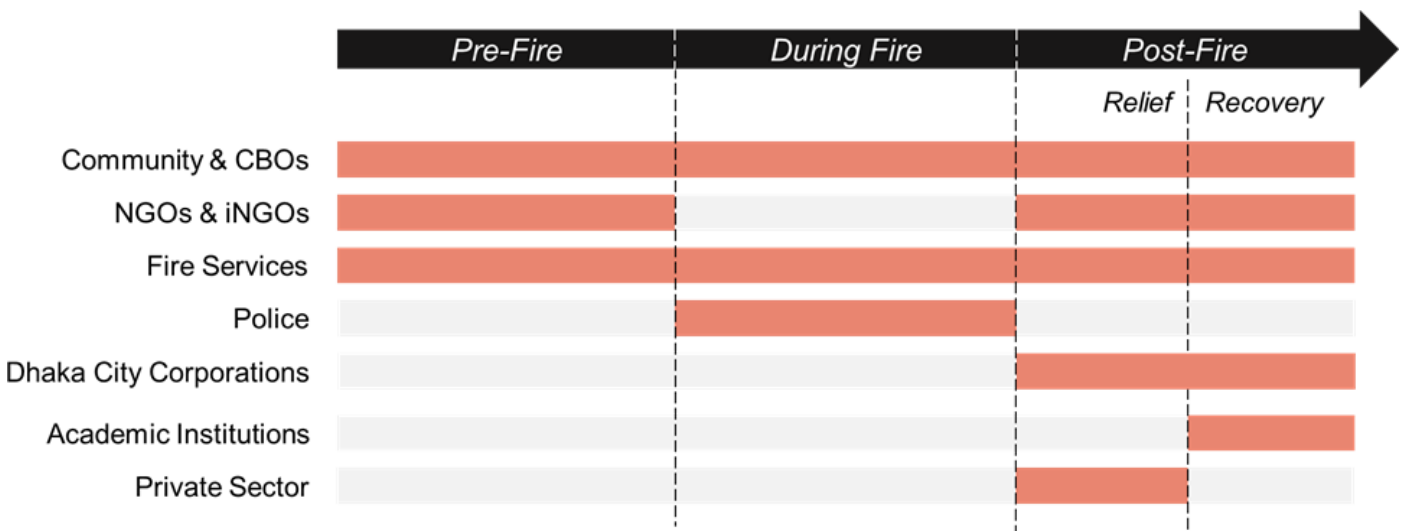

Figure 17: Stakeholders who may support fire safety before, during, and after a fire incident in an informal settlement in Dhaka

NGOs and international NGOs (iNGOs) provide support to informal settlement communities during the *pre-fire* time period. In Dhaka, providing social services, professional training and livelihood support, and microfinancing are common. As discussed in Section 5.2.1, there are limitations on what types of activities NGOs and iNGOs can support in informal settlements. Government endorsement is typically expected for projects, and incremental upgrading or re-blocking type projects are generally not supported; therefore, NGOs and iNGOs seldom carry out these activities. Even if they do have some government support, there is no guarantee that the settlement won't be evicted in the near future, meaning there is a high risk the investment may not be sustainable, which further dissuades these types of projects.

Fire safety seldom features as the primary focus of a program, nor as an intentional co-benefit. However, there are a couple positive examples of NGO programming. A large Dhaka headquartered iNGO (BRAC) led a community fire risk reduction project with a suite of 8 interventions, including distribution of networked heat detectors/alarms and other fire safety products, as well as community-based fire safety training, provided in collaboration with the local fire services. Despite the perceived success of this pilot project, it has not been extended or replicated, albeit this is partly due to attention shifting to the Covid-19 pandemic. Separately, an iNGO (World Vision) also led a fire safety pilot project where heat detector/alarm devices were installed in informal settlements, however this project seems to have also been a one-off initiative.

FSCD has provided community-based fire safety training and education in informal settlements in connection with the above-mentioned pilot projects, as well as through their own initiatives.

However, this training seems to be provided on an ad hoc basis and efforts to establish a network of trained residents do not appear to have been successful yet due to challenges staying in touch with individuals who have undergone initial training. Resource constraints within FSCD are a significant barrier to ramping up and improving these programs. Sustainability of such initiatives is therefore a key issue.

Like Cape Town, the primary stakeholders involved in fire response are the people living in the area affected by the fire, the fire services, and police. The role of the police is largely crowd control. While tensions may rise between stakeholders during a fire and this may lead to negative verbal interactions, physical conflicts do not appear to be an issue in Dhaka.

Considering fire is sometimes used as an eviction tool in Dhaka, relief and recovery may not be provided on site after some fires. Displacement may be the direct result of a fire. However, when affected residents can remain on the same land, they may receive disaster relief support from NGOs, iNGOs, or the private sector. Dhaka City Corporation may provide financial support although this relief is often facilitated by an NGO. This is also the way government most often provides support for fire recovery, if at all. It is rare for a City Corporation to engage directly with communities, and NGO partners are therefore critical links. NGOs and iNGOs may provide support for recovery but this is often in the form of material distributions rather than settlement or dwelling planning, design, and construction. There are exceptions, however. After the March 2017 fire in Korail informal settlement, the government provided financial support and some oversight for a post-fire reconstruction project which was facilitated by a large NGO. An academic institution provided technical input on design of the area to be reconstructed.

There is limited communication and coordination to support fire safety in informal settlements, and a lack of clear responsibilities and lines of accountability. There is limited pressure on political constituencies to address fire in informal settlements, related to the low level of political commitment to the issue. Like other urban fire challenges in Dhaka, media coverage appears to garner the public's attention for only a short period of time, which may be reflective of low safety expectations of the public, possibly related to the multitude of other hazards people are exposed to in daily life in Dhaka.

Past efforts to improve fire safety have been tactical, focused on reducing fire hazards and vulnerabilities at the community or settlement level. (e.g., improving waste management, fire drills, cooking safety education). No evidence was found of past or current strategic fire safety interventions which address underlying dynamic pressures or root causes, nor was there evidence of fire safety being integrated into wider disaster risk reduction or development efforts to address dynamic pressures or root causes. In general, fire safety in informal settlements does not appear to be institutionalized into disaster risk reduction, urban development, or poverty alleviation efforts.

Despite the lack of mature discourse on the issue of fire in informal settlements in Dhaka, stakeholders acknowledge its significant impact. Interviewees highlighted the lack of local technical and institutional capacity to address this issue and appeared eager to engage with the topic in the future and to provide support to improve fire safety.

Improving fire safety in complex adaptive systems

The current status of fire safety systems in Dhaka and Cape Town is characterised by a lack of

oversight, governance, and thus communication and coordination between all relevant actors. There is also a narrow focus on fire hazard as opposed to fire risk emergence and underlying root causes. Broader conversations are needed around service delivery, *in situ* incremental upgrading, and the reduction of structural constraints, bringing in a wider range of city actors. Communities and residents are particularly excluded from city level conversations about developing solutions, despite the central role they have in preparing, responding to and recovering from fire, and the disproportionate risk that they bear. This lack of effective governance has knock-on effects for effective responses. This can be seen as contributing to fire risk emergence, in that fire risks develop into actual disasters, and disaster consequences cascade into feedback loops.

Rather than emulating top-down command and control fire safety systems, institutionalisation of collaborative fire safety is needed, that takes into account and supports the important role that all actors play [116]. This would help the whole system to bear accountability and responsibility, to counter the focus on 'responsibilisation'[7] of informal settlement residents for fire risk that emerges from across the city and not just at the point of ignition. Such an approach also takes into account the reality of informal settlement contexts for which formal command and control fire safety systems are inappropriate. The fundamental assumptions that underpin the success of formal fire safety systems do not apply in informal settlements (e.g., separations

[7] "Responsibilization' refers to the process whereby subjects are rendered individually responsible for a task which previously would have been the duty of another – usually a state agency – or would not have been recognized as a responsibility at all." [140]

between buildings prevent fire spread, speedy response of fire services). The command-and-control approach minimizes the role of the public in protecting themselves from fire (before, during, and after an incident), which is not reflective of the reality, especially in informal settlements where residents are the only stakeholders able to respond quickly. [116] [94] There is therefore a need for more organized and supported community-based fire response.

A supporting and enabling approach recognises that communities and residents must be worked with to inform holistic fire safety solutions which navigate local barriers and leverage resources. Improved fire safety subsystems can be adapted; for example, fire services could adapt their policies, procedures, training, and equipment to the unique fire risk experienced in informal settlements, community-driven fire safety systems could be prioritised and resourced by municipal authorities, and urban fora created for ongoing communication and coordination between stakeholders with the shared goal of improving safety outcomes. The aim of this approach is not to engineer fire safety systems for informal settlements, but to better understand risk emergence and connect this to contextually appropriate fire safety interventions. Resourcing is a key issue, particularly in the context of LMIC cities, however a step change in approach is urgently needed, which aims to avoid catastrophic losses.

6. Conclusions and recommendations

The research has been able to show interactions between system components previously considered unrelated or not taken into consideration by more traditional engineered approaches, and recommend fire safety interventions informed by this more

realistic, complex understanding of fire risk and fire safety.

Fire risk emerges from deeply rooted national and urban histories and unique socio-economic, political, and environmental contexts. In both cities – Cape Town and Dhaka – structurally constrained conditions limit people's choices of where and how to live safely, ultimately leading to a multitude of ignition sources and conditions that support fire spread. Limited infrastructure and institutional capacity to respond to fires allows small fires to grow into large conflagrations, sometimes affecting thousands of people. While some engineered fire safety subsystems from formal areas may extend to informal settlements, such as fire services response, these are generally not fit for purpose for informal settlements, which rely on ad hoc (often community driven) fire safety systems. Overall, this means fire safety in informal settlements is a hybrid system, comprising some engineered fire safety systems (e.g., fire services response) and some ad hoc fire safety systems. Diverse socioeconomic and political vulnerabilities amplify the consequences of fire and exacerbate the risk of future fires. Local factors in each city and settlement drive fire risk and shape capacities and capabilities for fire safety.

Informal settlements are often considered temporary in theory but permanent in practice. This dichotomy creates tension between informal settlement residents and the formal systems which they are governed by, which influences fire risk emergence in Cape Town and Dhaka and is closely associated with tenure (in)security, energy (access and choices) and economic activities of the informal economy. In general, there is a lack of data and research on fire risk and fire safety in informal settlements in Bangladesh. [69] Where data is available through

research in Cape Town, much of it focuses on very few locations and incidents, particularly in and around larger cities.

Fire incidence responses in informal settlements face challenges at every stage: fire detection is almost never available, relying on people to perceive fire cues; population response to fire incidences appear to be ad hoc although they have not been studied enough to derive any meaningful inferences; and fire services' response is often hampered by delayed notification, traffic, challenges finding the location of the fire, poor access due to a lack of road infrastructure, and poor access to water.

All the systemic failures to prevent and respond to fire ultimately lead to devastating consequences for informal settlement dwellers, who experience property loss, fatalities and injuries. Other direct and indirect consequences are rarely traced, through either qualitative or quantitative research methods, making it difficult to appreciate the full extent of consequences that people are faced with as a result of a fire, nor the direct relationship between fire incidents and further fire risk emergence (feedback loops).

Fire safety's notable absence from disaster risk reduction, urban resilience, and urban development discourses in both Cape Town and Dhaka means fire safety is not being addressed by the stakeholders with the most capabilities to avoid fire risk emergence and to manage fire risks and fire disasters. A lack of any central authority with regard to responsibility and accountability for fire risk and safety has been identified. Though it is important to note that stakeholders in both cities acknowledge the significant impact of fires in informal settlements and appear eager to engage and invest in fire safety, and to learn from research and practices across diverse contexts.

Whilst this research has addressed city institutional responses and perspectives; it is imperative to understand fire risk and fire safety practices from the perspective of communities and residents who live with high fire risk daily. Future research is urgently needed to document and share this knowledge and related adaptive practices. Helping communities to strengthen their capacities to protect themselves from fire and fostering an enabling environment that supports and encourages the emergence of local fire safety practices may be the most achievable and scalable way to improve fire safety and fire resilience in informal settlements. [117] Engagement with diverse stakeholders (governmental and non-governmental) is critical to develop an understanding of their role and location within the system, power relations between them, and the actual roles and responsibilities that they perform whether designated or not. While there are opportunities to incrementally improve fire safety in informal settlements, through service delivery, in situ incremental upgrading, the removal/reduction of structural constraints, and where appropriate engineering certain subsystems to be fit for purpose, it is critically important that the ad hoc nature of informal settlements is respected and that an enabling environment that promotes the emergence of fire safety is prioritized.

7. Transferrable learning to safety of complex systems

Principles applied in this research study can contribute to the wider Disaster Risk Reduction field. For example, consideration given to fire risk as an endogenous hazard emerging within the everyday lives of people and their everyday practices, can be applied when considering other hazards, such as biological hazards (e.g., Covid-19). This thinking reinforces the increasingly accepted thinking within DRR that many hazards are socially produced.

The methodology and findings of this study can also be used to better understand and tackle socio-technical issues. Engineering and social sciences can work together to interrogate and understand systems and stakeholder groups, thereby developing more holistic problem definitions and more appropriate and effective solutions, including more effective contextualisation of foreign interventions. This is key when considering whether formal components (e.g., codes and standards) are appropriate for informal parts of a system (e.g., informal settlements). Not all components can or should be 'formalised' but rather the concept of a spectrum of (in)formality, rather than formal versus informal systems, should be taken into consideration.

It is important to consider the positive effects of an institutional-level (e.g., public or private institution) approach to fire issues and how this can support tackling bottom-up emergence of fire hazard. As it has been argued in this report, fire issue is socio – technical, thus meaning that effective implementation of fire safety must consider people's daily lives and institutions' effects on them. Self-reflection by institutions on their own roles and their impacts (either through policy or operations) is one such approach. If an institution is capable of such self-reflection, it could identify what parts of their institutional processes produce barriers to achieving fire safety in a complex system, as shown through complex interactions mapped in this report. It can also help identify what role the institution has in relation to other stakeholders, together with pinpointing what capabilities exist to build relationships between these stakeholders. The proposed (fire) risk complex adaptive systems framework and the

web of institutionalization can be powerful tools for self-reflection and interrogation of the system. Due to their flexibility, it can be adapted to specific issues to help better understand risk emergence, interactions of hazards and vulnerabilities, and between stakeholders.

Finally, the general principles discussed in this report are a precedent to finding generalised solutions for common problems, showing that complex systems work in similar ways across diverse contexts. It has been shown that the local nature of fire or any other risk may share principles, and therefore, the process of mapping the systems is generalisable, even though the specificities may not be. This has been shown in this report through the selected methodology and mapping the key emerging risk categories for two very distinct places with unique histories.

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Affiliations

Danielle Antonellis, Founder & Executive Director, Kindling

Laura Hirst, Advisor, Kindling

John Twigg, Advisor, Kindling

Sandra Vaiciulyte, Senior Fire Safety Researcher, Kindling

Reasat Faisal, Senior Urban Development Specialist, Kindling

Melissa Spiegel, York University

George Faller, Advisor, Kindling

Prof Richard Walls, Professor of Structural & Fire Engineering, Dept of Civil Engineering, Stellenbosch University

Dr Natalia Flores-Quiroz, Post-Doctoral Researcher, Department of Civil Engineering, Stellenbosch University

Birgitte Messerschmidt, Director of Research, National Fire Protection Association

Appendix A: Web of Institutionalization

The web of institutionalisation is a diagnostic and operational framework originally developed by Caren Levy (1996) for the institutionalisation of a gender perspective in development policy, planning and practice. [24] It helps to identify sites of political power (in terms of institutions and assets) and connect them with planning and policy practices. It identifies thirteen elements which each represent a site of power, and which are linked, interrelated, and reinforce each other. A series of questions guides analysis of each element. Although originally applied to a gender perspective, later applications have used it to explain the linkages between governance, social sectors, processes, structures and actions in any situation that involves political institutions. [118] Boano and Marten (2017) note that the framework can be useful for 'investigating specific urban environments such as informal settlements or risk-prone

areas – how they are understood and produced, and how they embody meanings, identities, practices, and power relationships' (p.16).

The web was used in the initial phase of the research to categorise and broadly map the team's existing knowledge and experiences from the field with regards to fire risk emergence and fire safety. **Figure 18** shows the original Web of Institutionalisation. **Figures 19 and 20** show the web maps for each city that were created in the mapping workshop. Red text represented opportunities for fire safety, whilst black text related to potential risk emergence factors.
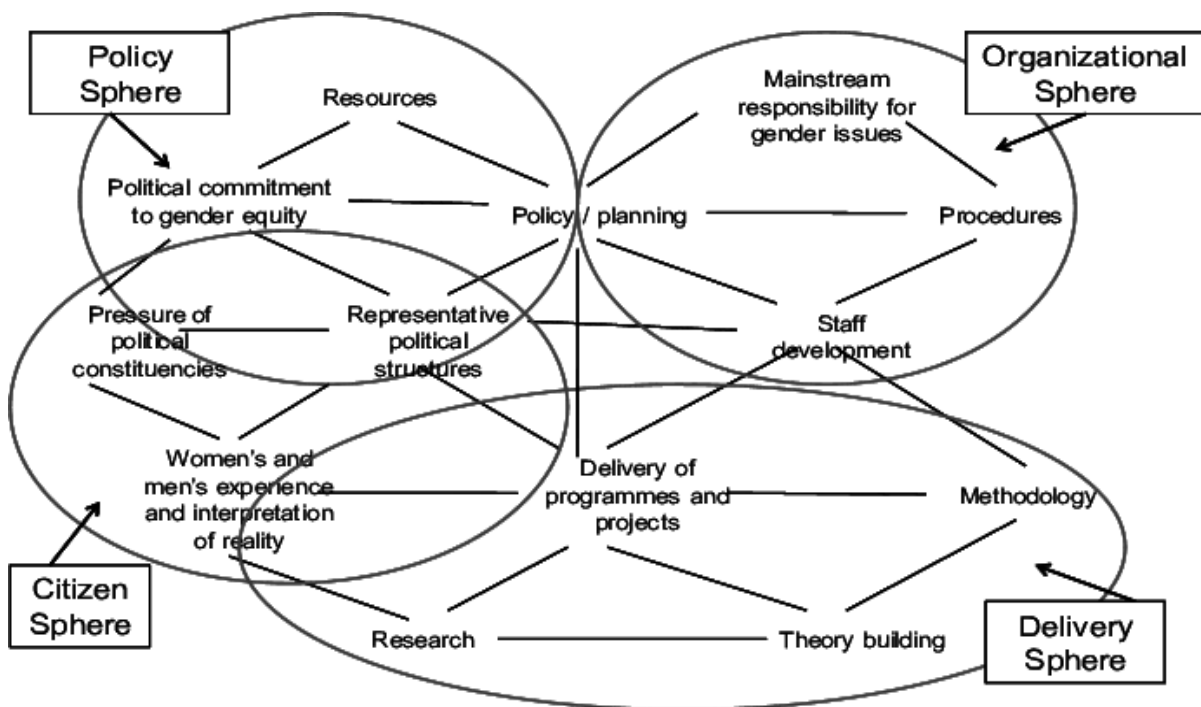

Figure 18: The Web of Institutionalisation. [24]

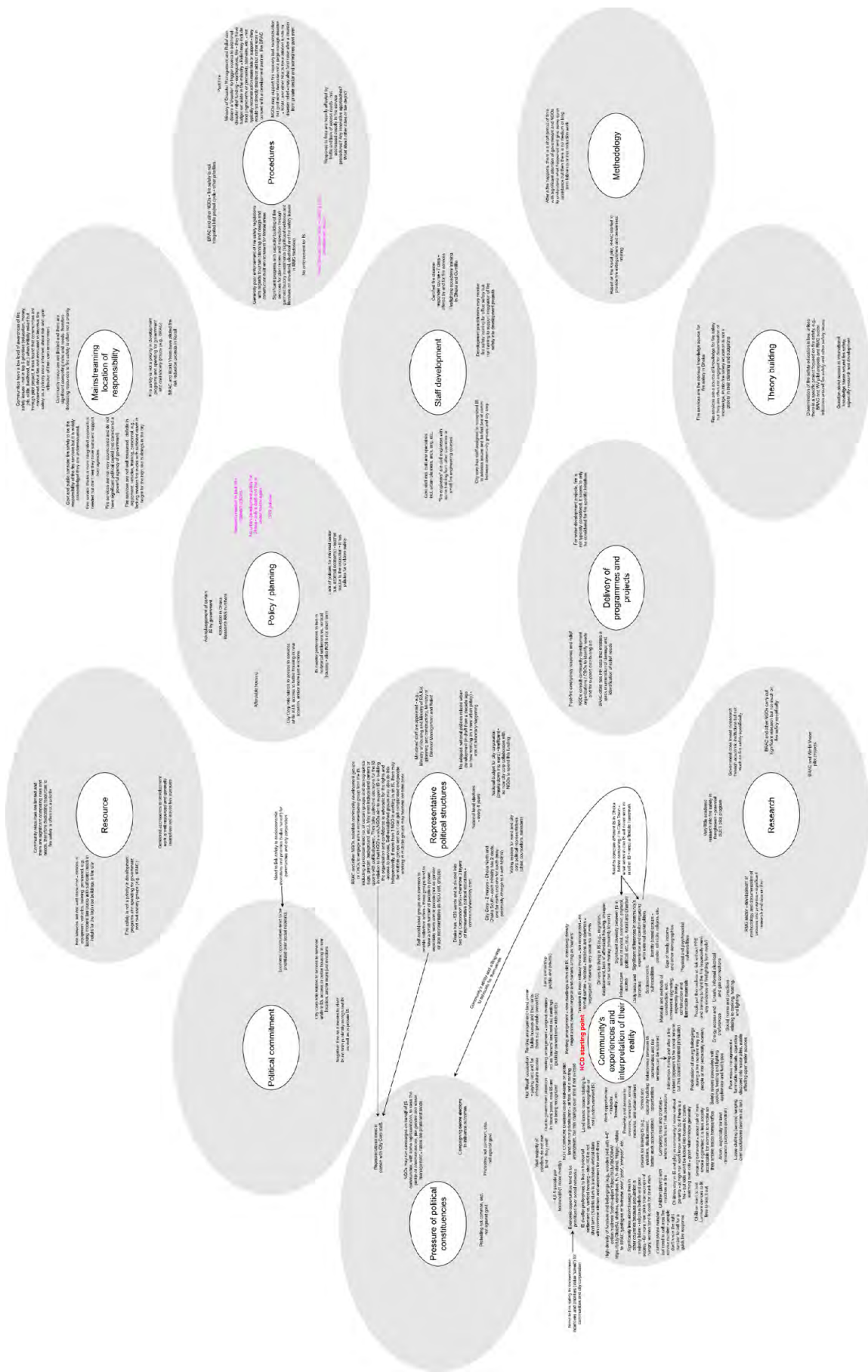Figure 19: Web map for Cape Town created during team workshop 24th March 2021

Figure 20: Web map for Dhaka created during team workshop 24th March 2021

Appendix B: Semi-structured interview questions

Questions applicable to all interviewees:

- What is your role within your organisation?

- What do you think are the major issues affecting people living in informal settlements?

- What are the major challenges of working in informal settlements? How does your organisation deal with these challenges?

- What programmes/projects does your organisation carry out in informal settlements?

- Does your organisation collaborate with any other organizations for these projects/ interventions? What was the approach of collaboration?

- In what way does your organisation work on the issue of fire in Cape Town/Dhaka?

- Could you give your view of the fire problem in informal settlements?

- Can you describe the major challenges of working on fire in the IS based on your experience and knowledge?

- Does your organisation collaborate with any fire safety organisations/professionals?

- What type of economic activities or businesses are you aware of in informal settlements?

- What are the causes and social catalysts of fires in informal settlements?

- What can be done before an incident to prepare for future fires?

- Which stakeholders are involved with fire safety before an incident, for fire prevention, mitigation, and preparedness activities?

- Which actors are involved during or after a fire incident, to support fire response and recovery efforts?

- What are the impacts and consequences of such fires?

- What is being done to address the fire problem in informal settlements? By whom?

- Who do you think holds responsibility for fire safety in informal settlements?

- Are there any common drivers for arson or deliberate fires in informal settlements?

- Does anyone benefit from fire?

- Is urban fire risk management a part of Disaster Risk Reduction (DRR) conversation?

- Is urban fire risk management a visible part of development conversations?

- Do you think fire is considered as a priority?
  - At the community level?
  - at the local/city level?
  - at the national level?

- What role can international agencies play in reducing fire risks in informal settlements?

- What change do you want to see to improve fire safety in informal settlements?

Supplementary questions for non-governmental organisations:

- What are IS community perceptions of the fire issue in their area?

- What activities do informal settlement dwellers engage in, in the event of a fire?

- Can you describe how people's diverse abilities and vulnerabilities may shape their response to fire?

- How do affected/displaced households recover from a fire incident? What support do they receive from…
  - Family/friends/neighbours living inside the informal settlement?
  - Other family and friends?

- Wider community in the area?
- NGOs or other organizations?

Supplementary questions for academic institutions:

- What data/research exists on fire related issues in your city?

- Do you think there is enough data/research conducted/ available on fire related issues in IS? If not, why not?

Supplementary questions for government (fire services and disaster management agencies):

- Have you observed any changes in informal settlement fires over time?

- Can you describe the relationship in general between the fire services and informal settlement communities?

- Please describe the main challenges with fire service response to fires in informal settlements in the city?

- What is the standard procedure for fire response to informal settlements, e.g., predetermined attendance, crowd control, firefighting tactics?

- Is there any training for firefighters to prepare them for informal settlement fires?

- What types of interactions are there between informal settlement dwellers and firefighters during fire incidents?

- How does the public perceive the fire services in Cape Town/Dhaka? What are their expectations of the fire services?

- How do other government agencies perceive the fire services?

- Does your organisation receive sufficient financial funding?

- What are your departmental priorities with regards to IS fires (e.g., increasing response capacity, innovative technologies, code compliance, community engagement)?

Supplementary questions for government (urban planning and development agencies):

- Does urban planning or current infrastructure of the informal settlements impact fire risk?

- Can you describe the relationship in general between the City and informal settlement communities?

- What policies exist which relate to fire risk in the city? Are these adequate? How are they implemented?

- Is there budget allocation for fire risk in informal settlements?

- What data is held on fire incidents? How is this data used?

- How does urban planning address fire risk in informal settlements?

- What fire safety training or support for informal settlements exists?

- What are the fire risks associated with basic services in the city (water, energy, housing, infrastructure) and how are they impacted by fire?

Appendix C: Interviews

City	Organization	Date of Interview
Cape Town	Thula Thula	Pre-recorded interviews made available by Stellenbosch University
Cape Town	Stellenbosch University	
Cape Town	Stellenbosch University, Risk Alliance for Disaster & Risk Reduction (RADAR)	
Cape Town	City of Cape Town Fire Services	
Cape Town	Western Cape Department of Human Settlements	
Cape Town	Western Cape Disaster Management Centre	
Cape Town	Save the Children International	August 3, 2021
Cape Town	Sustainable Livelihoods Foundation	August 5, 2021
Cape Town	Western Cape Fire & Rescue Services	August 5, 2021
Cape Town	Resilience Shift	August 5, 2021
Cape Town	Landworks	August 6, 2021
Cape Town	University of Cape Town African Centre for Cities	August 6, 2021
Cape Town	Western Cape Department of Human Settlements	August 10, 2021
Cape Town	Stellenbosch University, Risk Alliance for Disaster & Risk Reduction (RADAR)	August 10, 2021
Cape Town	Development Action Group	August 11, 2021
Cape Town	Ikhayalami	August 12, 2021
Cape Town	City of Cape Town Fire Services	August 13, 2021
Cape Town	Formerly IRIS-FIRE, University of Edinburgh	August 13, 2021
Cape Town	City of Cape Town Human Settlements Directorate	August 20, 2021
Cape Town	The Craft + Design Institute Better Living Challenge	August 20, 2021
Cape Town	University of Edinburgh	August 24, 2021
Cape Town	Western Cape Department of Human Settlements	August 30, 2021
Dhaka	United Nations Office for Project Services	June 2, 2021
Dhaka	World Bank	June 14, 2021
Dhaka	Fire Service and Civil Defense	June 20, 2021
Dhaka	World Vision	June 22, 2021
Dhaka	Bangladesh University of Engineering and Technology	June 23, 2021
Dhaka / Cape Town	Lumkani	June 23, 2021
Dhaka	Plan International	June 24, 2021
Dhaka	Save the Children Bangladesh	July 4, 2021
Dhaka	BRAC	August 10, 2021