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Urban Fire Risk Management in Dar es Salaam, Tanzania: A Spatial, Operational, and Institutional Assessment

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ABSTRACT

Fire incidents pose a significant threat to urban residents in Dar es Salaam, Tanzania, particularly within high-density unplanned settlements. This study assessed urban fire risk management in Dar es Salaam City, examining spatial-temporal incident patterns, institutional response capacity, and infrastructure performance. A convergent parallel mixed-methods design was employed, integrating Key Informant Interviews, Focus Group Discussions, structured field observations, and secondary fire incident records (2016–2020) with ArcGIS-based spatial analysis, including Kernel Density Estimation, Network Service Area Analysis, and one-way ANOVA. A total of 2,119 fire incidents were recorded, with Ilala Municipality recording the highest incidence (n=603; 28.45%), followed by Kinondoni (n=548; 25.86%), Ubungo (n=427; 20.15%), Temeke (n=285; 13.45%) and Kigamboni (n=256; 12.09%). Residential and institutional structures accounted for 76% of all incidents. Rescue success rates remained critically low, rising from 4.3% to 13.2% with Ubungo recording the lowest municipal rate (11.1%) due to the absence of a dedicated fire station. The study recommends assessing the feasibility of, and where appropriate implementing the decentralization of fire station distribution, rehabilitating non-functional hydrants, adopting digital spatial data management systems, and integrating fire safety standards into urban planning frameworks.

Key words: fire; rescue; emergency; incidents; unplanned; planned

INTRODUCTION

Fire disasters occur in most parts of the world, especially in cities, posing a hazard to the environment, properties, and people, leading to physical injuries, psychological damage, death, and significant economic losses (Hargono *et al.,* 2023; Yunus, 2019). Fire disaster preparedness is an important element in the reduction of disaster risks by creating awareness and readiness of communities to mount appropriate responses and achieve recovery (Bali, 2022; Moses *et al.,* 2024; Ryan *et al.,* 2020). Thus, disaster risk reduction is an area of concern for sustainable development due to its extreme impacts that are beyond what communities can bear. In Africa, fire cases are reported across several countries. For instance, according to national fire statistics released by the Federal Fire Service in 2021, Nigeria reported 2,845 fire outbreak cases with financial losses of approximately USD 2 billion. Between 2020–2024, Kenya reported 1,606 fire cases with 293 fatalities (ICHA, 2025). In 2024, Rwanda recorded 102 fire cases in the city of Kigali (RNP, 2024). However, the magnitude of fire outbreaks depends on the level of exposure and vulnerability of affected settlements that have few resources to protect residents in fire emergencies (Mandalapu *et*

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al., 2024; Mtani and Mbuya, 2018). These statistics clearly indicate that serious attention is urgently needed regarding fire service response and recovery systems in developing countries.

In Tanzania, assessment of potential hazards has clearly identified fire as a significant human-made disaster. Such fire disasters are particularly common in crowded central business districts, and cities (Mtani and Mbuya, 2018; Zhang *et al.,* 2020). Dar es Salaam, being no exception, has experienced a number of fire outbreaks. A key concern relates to urban planning, where the gap between the rate of population growth and the pace of urban infrastructure planning is significantly wide (Kihila, 2017; Mtani and Mbuya, 2018). Fire outbreaks have been recorded across residential, commercial, educational, and office buildings; fire outbreak trends in residential buildings are consistently higher than those in other building types (Stemn *et al.,* 2025). Consequently, congestion, poor urban infrastructure for firefighting, lack of training and awareness, poor accessibility, and high building density increase fire risk, especially in unplanned areas, city centers, and markets, thereby compounding the fire emergency response challenge (Kihila, 2017; Mtani and Mbuya, 2018; Phyo Wai *et al.,* 2025). Despite the existence of Fire and Rescue Management Departments responsible for emergency response services, limited empirical evidence exists on the effectiveness of these management systems and the operational difficulties encountered in rapidly urbanizing cities. This gap is particularly critical in Dar es Salaam, where unplanned settlement expansion, infrastructure deficits, and increasing population density continue to heighten fire risk (Kihila, 2017; Mtani and Mbuya, 2018). Therefore, this study examines the effectiveness of urban fire response relative to identified fire hotspots in the city.

MATERIALS AND METHODS

Description of Study Area

Dar es Salaam City has an area of about 1,393 square kilometers and is divided into three ecological zones, namely the upland zone, the middle plateau, and the lowlands. It has five (5) Municipal Councils, namely Temeke, Kinondoni, Ilala, Ubungo, and Kigamboni, which are embedded in the administrative structure of the Dar es Salaam Region. According to the 2022 population census, Dar es Salaam City had a population of 5,383,728, of whom 2,600,018 were male and 2,783,710 were female. According to NBS (2025), the city's current population is estimated at 8,562,000 and is projected to increase to 10 million by 2035.

Research Design

This research employed a convergent parallel mixed-methods research design, in which both primary and secondary data were collected concurrently and subsequently integrated to provide a comprehensive assessment of fire risk management. This design was selected because it enables triangulation of quantitative spatial data with qualitative institutional perspectives, thereby strengthening the validity of findings (Creswell and Plano Clark, 2018).

Sampling and Data Collection Methods

The study employed purposive sampling technique to collect primary data. Purposive sampling was deemed appropriate given the need to engage participants with direct operational knowledge of fire and rescue management (Patton, 2002). Key Informant Interviews (KII) were conducted with senior personnel from the Communication, Operational, and Control departments across three major fire stations (Ilala, Kinondoni, and Temeke); these stations were selected as they represent the primary operational hubs collectively serving all five municipalities. A total of nine key informants participated, selected based on their institutional roles and a minimum operational experience of

five (5) years. These were supplemented by three (3) Focus Group Discussions (FGDs), each comprising four specialized participants, totaling twelve participants, drawn from fire officers and emergency coordinators, to identify systemic operational bottlenecks. The FGD size was considered adequate for capturing diverse operational perspectives within a specialized institutional context (Morgan, 1997). Physical observations were also conducted using a structured observation checklist covering firefighting infrastructure such as hydrant locations, equipment condition, road accessibility and station facilities as well as operational response activities. Secondary data consisted of a comprehensive review of historical fire incident logs from 2016 to 2020, sourced directly from the Tanzania Fire and Rescue Force records. It is acknowledged that secondary fire incident data may be subject to underreporting bias and inconsistencies in recording practices.

Analytical Framework and Spatial Modeling

The data were integrated through a multi-layered analytical framework. Temporal trends were analyzed to identify seasonal peaks, and spatial data were processed using ArcGIS 10.4. Kernel Density Estimation (KDE) was applied to identify statistically significant fire hotspots, using a bandwidth of 1,200 metres, selected based on the mean nearest-neighbour distance of fire incident points, which is a widely adopted data-driven bandwidth selection approach in urban fire spatial analysis (Chainey and Ratcliffe, 2005; Silverman, 1986). To assess the spatial variation of socio-economic impacts across the study area, a one-way ANOVA was performed to compare the mean frequency of fire-related fatalities among the five municipalities to determine if municipal location significantly influenced life-safety outcomes. In addition, the Network Analyst extension in ArcGIS was used to perform a Service Area Analysis, modelling fire station service coverage based on road network travel distance and estimated response time. The road network dataset was sourced from OpenStreetMap, supplemented where necessary by municipal GIS data from the Dar es Salaam City Council, to ensure adequate coverage of both arterial and local road networks. An average travel speed of 40 km/h was assumed, consistent with urban fire response modelling in sub-Saharan African cities (Kihila, 2017), reflecting the congested road conditions characteristic of Dar es Salaam's high-density urban core. Finally, qualitative data from interviews and FGDs were triangulated with spatial results to provide a multi-layered understanding of the institutional and spatial factors contributing to elevated fire risk in high-density urban areas.

RESULTS AND DISCUSSION

Spatial-Temporal Dynamics of Fire Incidents

The spatial-temporal analysis involved a dataset of 2,119 fire records from 2016–2020. Ilala, Kinondoni, Ubungo, Temeke, and Kigamboni reported 603, 548, 427, 285, and 256 fire incidents respectively from June 2016 to July 2020. The findings show a strong association between the frequency of fires, seasonal climatic variation, and urban morphological density, as shown in Figure 1. Fire incidents exhibit a distinct seasonal peak, with the highest number of cases occurring during the hot and dry months of June to August, with monthly case volumes consistently exceeding the annual mean. During the dry season, accelerated rates of wear and tear of machine parts and decomposition of waste, together with the potential rupture of pressurized containers and explosive materials at dumps, may contribute to heightened fire risk (Januszewski and Brzezińska, 2022; Milimo *et al*., 2021). According to Yao *et al.* (2024), temperature variability is a significant indicator of urban fire activity, with warmer temperatures

associated with higher urban fire frequency. These seasonal patterns are therefore contextually and regionally specific.

The number of annual incidents declined from 606 in 2016 to 485 in 2020. While this downward trend is notable, attributing the decline solely to infrastructure improvements or increased public awareness would be premature in the absence of supporting empirical evidence; alternative explanations, including changes in incident reporting practices or data completeness over the study period, cannot be excluded. This pattern aligns with Yao et al. (2024), who demonstrated that high fire frequency is associated with a combination of ageing infrastructure and high population density.

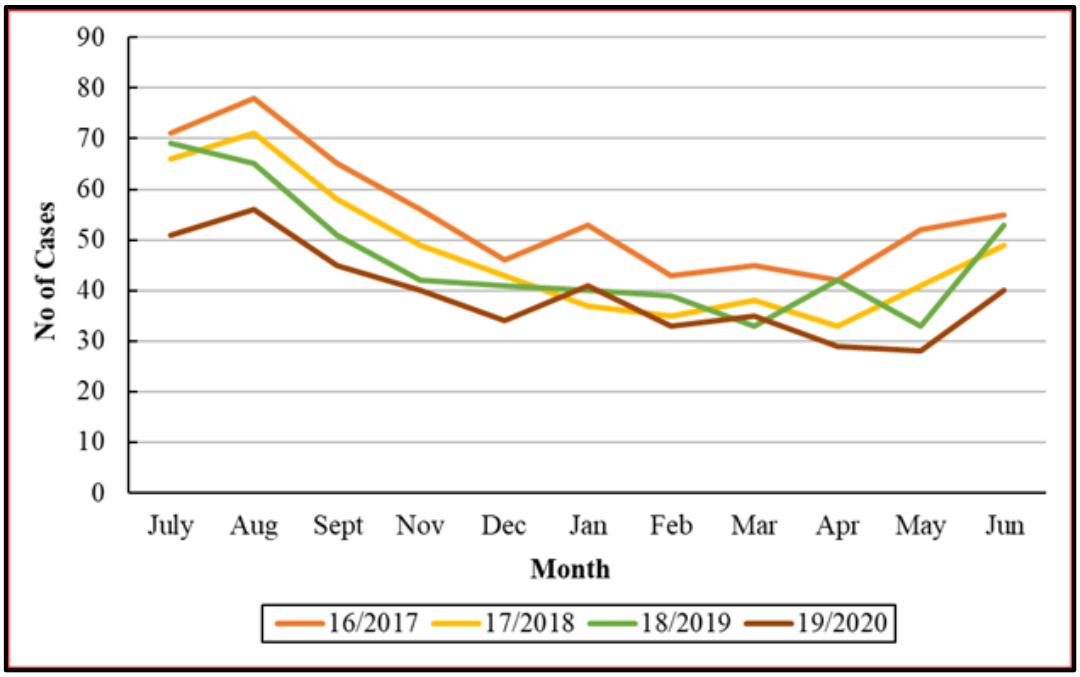

Figure 1: Monthly distribution of fire incidents in Dar es Salaam (2016–2020)

To further examine the spatial concentration of fire risks, a weighted Kernel Density Estimation (KDE) analysis was applied to the 2,119 incident records. Using a search bandwidth of 1,200m, the analysis identified hotspot clusters concentrated in high-density commercial and residential sectors, which coincide with vulnerable infrastructure (Figure 2). The highest kernel density values were recorded in Ilala CBD and surrounding wards, indicating zones of greatest fire concentration risk.

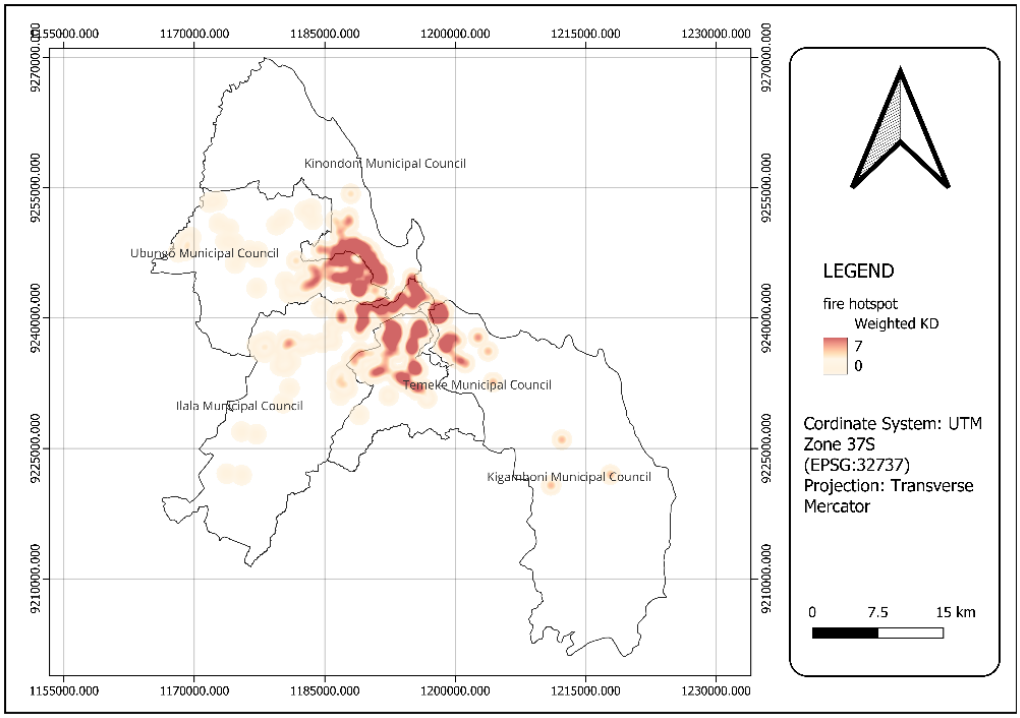

Figure 2: Fire incident hotspots in Dar es Salaam using a 1,200m bandwidth

In Dar es Salaam, the spatial distribution of fire incidents is spread across both the urban core and peripheral areas. As shown in Figure 2, Ilala recorded the highest incident frequency (n=603), attributable to its concentration of buildings, ageing electrical systems, and its role as the city's primary business and commercial hub. In contrast, Temeke and Kigamboni (n= 285 and 256 respectively) recorded comparatively lower incident frequencies; and although they contain several manufacturing facilities, fire safety compliance levels and housing density differ markedly from those observed in the unplanned high-density areas of the city centre.

Characterization of Fire Incidents

The distribution of fire events across space and time in 2119 incidents from 2016 to 2020 identified that most of the incidents occurred at residential areas. Although, a total of 76% of the total fires was attributed to residential and institutional (1605) building structures in unplanned wards, due to high fuel loads (Figure 3). Within the overall distribution of fire event causes, two major sources of ignition were reported during interviews. The first was structural and technical failure, where 287 incidents were classified as transformer fires resulting from inadequate maintenance. The second was vehicle-related fires, with 164 cases attributed to the use of counterfeit spare parts. In addition, 133 fire incidents in shops were linked to the rapid ignition of combustible materials, primarily due to high-density storage and close contact between flammable items. (Figure 4).

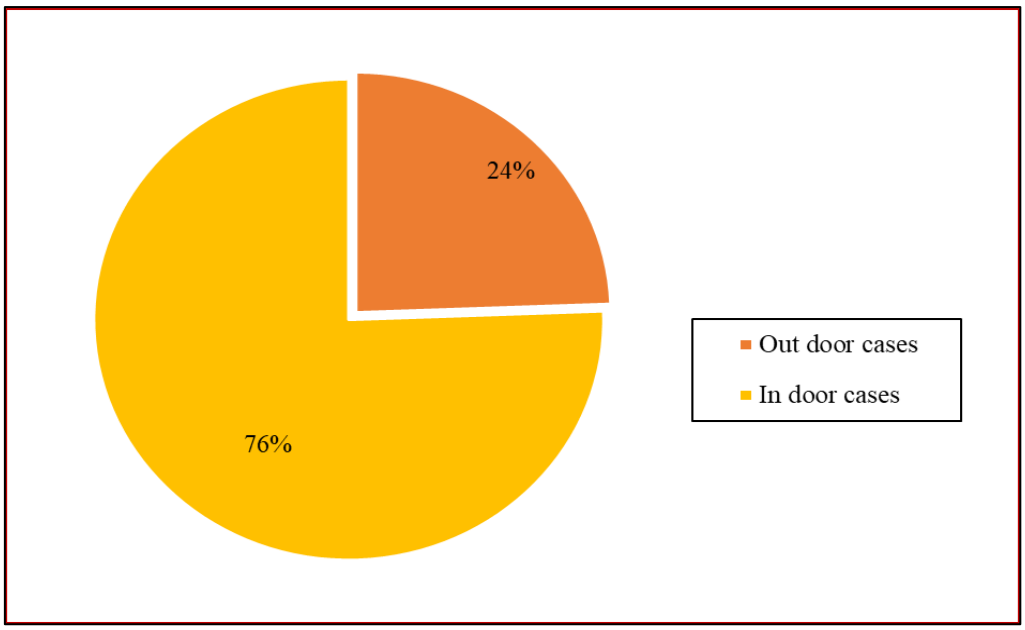

Figure 3: Categories of Fire in Dar es Salaam

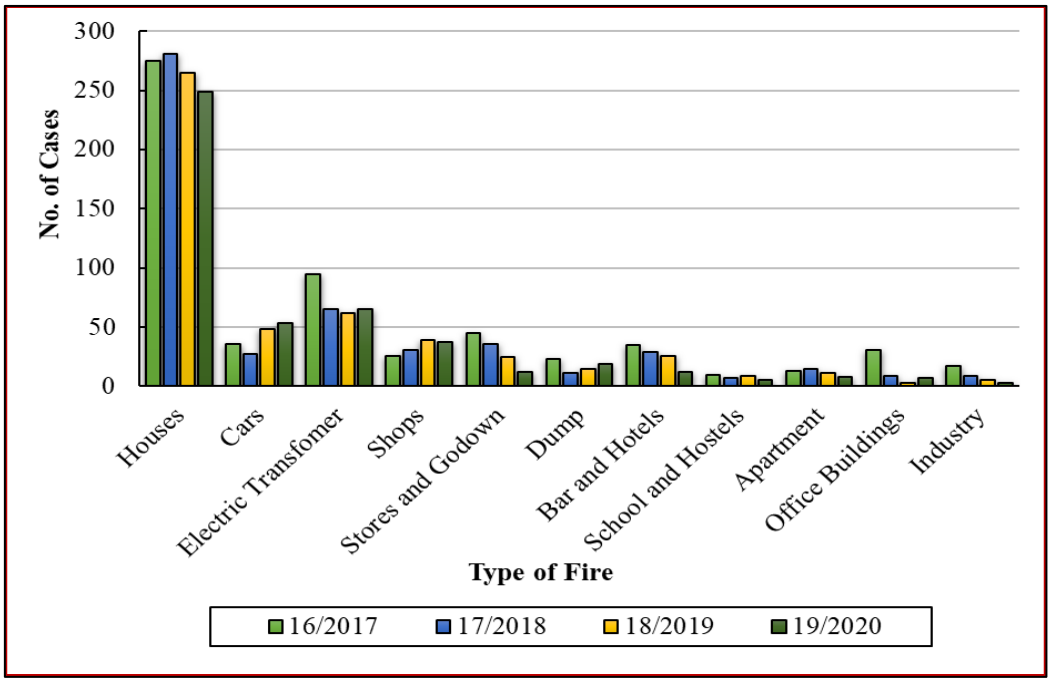

Figure 1: Characterization of Fire Incidents

Socio-Economic Impacts

The socio-economic impacts of fire incidents in Dar es Salaam are primarily reflected in the 311 documented fatalities recorded between 2016 and 2020, with the highest toll occurring in Ubungo and Kinondoni (131 deaths), followed by Temeke and Kigamboni (92), and Ilala (88) (Figure 5). The one-way ANOVA performed on the reported counts of fire-related deaths yielded a p-value of 0.2645, indicating no statistically significant difference in fatality frequency across the five municipal councils. However, this result should be interpreted with caution, as a non-significant p-value does not confirm equivalence but rather indicates insufficient statistical evidence to reject the null hypothesis at the conventional significance level ($\alpha = 0.05$). Fatality patterns appear to be associated with housing age, structural deterioration, and inadequate emergency

access in unplanned wards; however, these associations are observational in nature and should not be interpreted as confirmed causal relationships without further multivariate analysis.

It must be acknowledged that the socio-economic impact assessment in this study is constrained by data availability. Beyond fatalities, comprehensive data on fire-related injuries, property and asset losses, business interruption, household displacement, and institutional response costs were not systematically recorded in the source data obtained from the Tanzania Fire and Rescue Force. This absence of standardized multi-dimensional impact data represents a significant evidence gap and constrains the comprehensive evaluation of the full economic burden of fire in Dar es Salaam, a limitation addressed further in the study limitations section. The observed decline in fatalities over the study period (Figure 5) is encouraging; however, this trend should be interpreted with caution, as it may partly reflect changes in incident reporting practices or data completeness rather than confirmed improvements in life-safety outcomes alone.

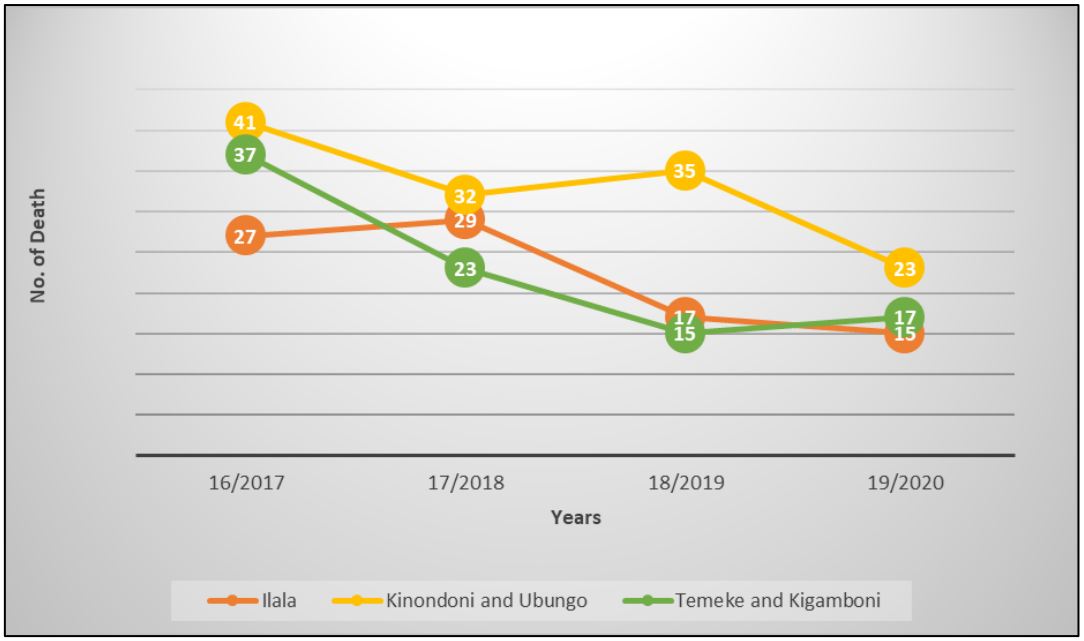

Figure 5: Fatalities due to Fire incidents in Dar es Salaam

Spatial Accessibility and Infrastructure Efficiency

In Dar es Salaam, there are four fire stations distributed at the municipal level, of which three are major stations and one is a sub-station. Fire suppression capacity is severely hampered by a so-called 'morphological trap', a condition in which dense and irregular urban form, isolates critical firefighting resources from high-risk fire ignition zones, as illustrated by the high-intensity Kernel Density Estimation (KDE) clusters in Figure 6; this isolation is most severe in the city's western fringes. Although the city records 75 public hydrants throughout its jurisdiction, only 30 are currently operational, with approximately 60% of non-functional units clustered in the city centre. Spatial network analysis using ArcGIS further revealed that within increasingly dense unplanned urban areas, the spatial lag between building locations and access to water supply is exacerbated due to the narrow road widths, which limit the maneuverability of standard firefighting vehicles. This physical infrastructure deficit is compounded by a critical shortage of firefighting personnel. The city has approximately 342 firefighters serving a population of over 6 million

residents, resulting in a firefighter-to-resident ratio of approximately 1:17,500. While direct comparison with international benchmarks requires contextual caution, this ratio falls substantially below staffing guidance for urban fire departments. It is acknowledged that NFPA 1710 (2020) was developed within the context of North American career fire service systems and may not be directly transferable to sub-Saharan urban settings without adaptation; it is therefore applied here as a general indicative reference rather than a prescriptive standard.

Spatial coverage analysis indicates that several high-density wards fall beyond a 5-kilometre response distance threshold from the nearest fire station. This 5 km threshold was adopted from the established methodologies in sub-Saharan African urban fire service assessments (Raji and Dalhatu, 2023), with the recognition that effective operational response depends not only on distance but also on road conditions, traffic congestion, and vehicle availability. The spatial overlay in Figure 6 confirms that a number of high-density ignition zones are located outside station coverage areas, particularly in Ubungo Municipality, which currently lacks a dedicated fire station. The spatial overlay reveals a notable absence of both station coverage buffers and functional hydrants within this high-risk area. These spatial deficiencies collectively suggest the need for consideration of a more decentralized fire station management model.

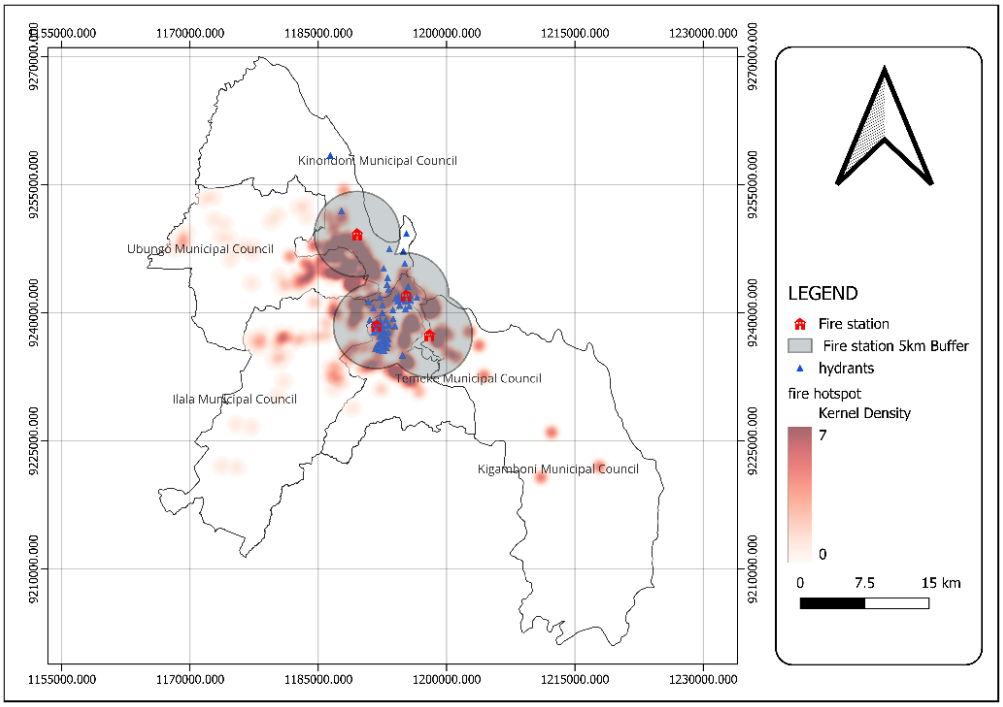

Figure 6: Spatial Mismatch between Fire Risk Intensity and Response Infrastructure

To ensure adequate personnel for effective fire suppression, rescue, and evacuation, it is recommended that there should be a minimum of 15 firefighters for urban structure fires, 10 for suburban, and 6 for rural structure fires, It should be noted that these benchmarks reflect operational conditions and infrastructure standards that differ significantly from those prevailing in Dar es Salaam; they are therefore applied here as indicative reference points to contextualize the identified staffing deficit, not as directly prescriptive standards (Kumar *et al.,* 2022).

Fire Incidents Relative to the Rescue Events

The efficiency of firefighting in Dar es Salaam is assessed using a locally defined 'Rescue Success Rate', defined in this study as the operational ability to mobilize resources and suppress a fire sufficiently before it results in total structural loss. According to data from the Tanzania Fire and Rescue Force, a persistent and wide gap exists between the number of recorded fire incidents and successful rescue events across all Municipals. In the 2016/2017 fiscal year, 606 incidents were recorded, of which only 4.3% resulted in successful rescues. In 2017/2018, there were 520 incidents and the success rate increased to 6.5%. By 2018/2019, incidents had declined slightly to 508, with a rescue success rate rising to 11%, while in 2019/2020, 485 incidents were recorded and the success rate further increased to 13.2% (Table 1). Despite this upward trend, overall rescue success rates remain critically low. While the gradual improvement in rescue success rates over the study period is encouraging, the underlying drivers of this trend, whether attributable to infrastructure investment, increased community awareness, or changes in recording practices cannot be confirmed from the available data alone. According to NFPA -1710 (2020) guidance for career fire departments, the recommended maximum travel time is 8 minutes from dispatch to arrival at the incident location. It is noted, however, that this standard was developed for North American career fire service contexts and its direct applicability to Dar es Salaam requires contextual adaptation; it is therefore applied here as a general indicative benchmark rather than a prescriptive standard.

Table 1: Fire Incidents and Rescue Success (2016–2020)

Fiscal Year	Total Recorded Incidents	Rescue Success (%)	Rescue Success (Count)	Efficiency Gap (Total Loss %)
2016/2017	606	4.3%	26	95.7%
2017/2018	520	6.5%	34	93.5%
2018/2019	508	11.0%	56	89.0%
2019/2020	485	13.2%	64	86.8%

The spatial inequality in rescue outcomes across Dar es Salaam highlights the influence of urban spatial configuration constraints, as evidenced by the 2019/2020 municipal-level rescue data. In Kinondoni, only 24 out of 138 recorded cases resulted in successful rescues (17.4%), while Ilala, despite hosting the nearest fire station to the city centre recorded 44 successful rescues out of 143 cases, reflecting a successful rescue of rate of 30.7%. In Temeke and Kigamboni combined, 18 out of 105 cases were successfully rescued (17.1%). The most critically underserved area remains Ubungo Municipality, where only 11 out of 99 incidents resulted in rescue (11.1%), directly attributable to the absence of a dedicated fire station and limited resource capacity within the municipality (Figure 7). This disparity is compounded by a physical infrastructure deficit; the reliance on large, standardized fire appliances in narrow, unplanned street networks creates accessibility constraints across the 'last mile', necessitating time-consuming hose relays that extend response times far beyond the NFPA 1710 8-minute guidance threshold. With a firefighter-to-resident ratio of 1:17,500, the centralized management system means that by the time crews navigate from stations such as Kinondoni to high-risk zones in Ubungo, most incidents have already escalated to full structural flashover. These findings collectively point to the potential value of a decentralized fire station management model as a strategy to reduce the systemic

response delays responsible for total structural loss across vulnerable wards.

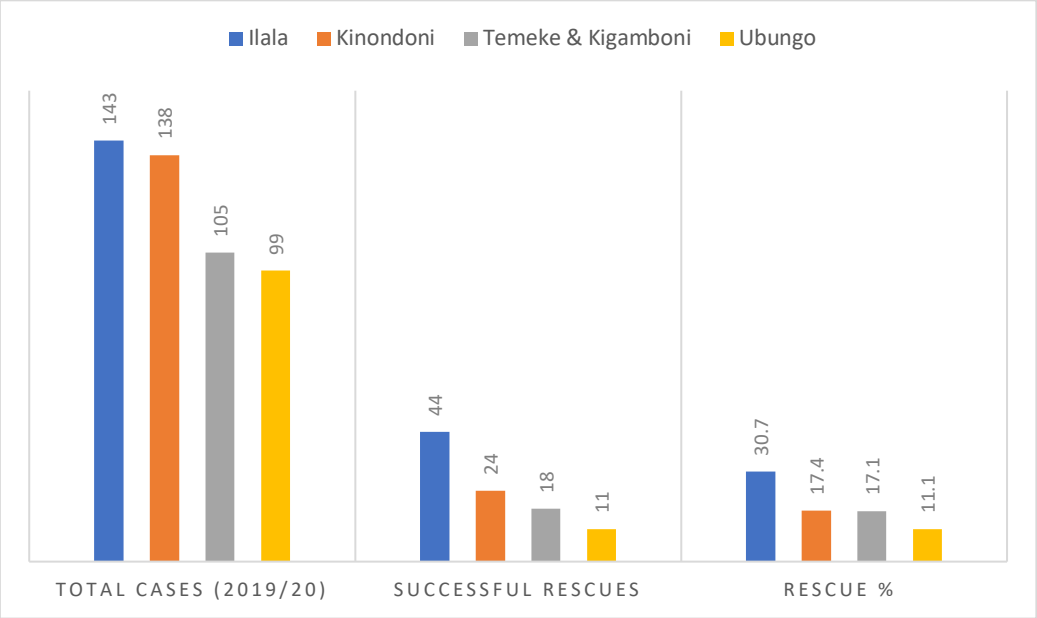

Figure 7: Total Fire Incidents vs. Successful Rescue Events by Municipality

Challenges of Fire Management System

The emergency response services in Dar es Salaam are substantially burdened by multiple interrelated limitations and challenges. These include inadequate financial support for equipment procurement and maintenance, the absence of a digital spatial database for incident tracking and resource deployment, inconsistent data recording practices, unreliable operational technology, and significant physical accessibility constraints in reaching fire incidents within dense unplanned settlements. Fire management systems worldwide face challenges that are interrelated and stem from the built environment, institutional framework, and the social systems that exist within those institutions. These dimensions are deeply interconnected; physical infrastructure deficits, such as those identified in this study, including inadequate hydrant networks, narrow road access, and centralised station distribution cannot be effectively addressed without concurrent institutional and governance reform (Kihila, 2017; Mtani and Mbuya, 2018).

Scholarly research demonstrates that effective response to fire crisis requires the simultaneous management of physical, behavioural, and institutional dimensions. Jiang *et al*. (2022) demonstrated that the three necessary conditions for safe and effective evacuation during a fire incident relate to the building's physical characteristics, fire dynamics, and human behaviour, and that effective management of fires in the built environment requires the integration of facility design, occupant behaviour, and technology to facilitate effective evacuations. Similarly, Okechukwu *et al.* (2025) identified comparable operational and institutional constraints within the Nigeria Fire Service, including a lack of civic responsibility, insufficient institutional capacity, and an absence of a learning culture as key obstacles in the provision of effective emergency services. These findings are directly relevant to the Dar es Salaam context, where this study similarly identified institutional fragmentation,

limited inter-agency coordination, and the absence of standardized data management systems as compounding factors that reduce fire response effectiveness beyond what physical infrastructure alone can explain.

From an urban planning and governance perspective, the challenges identified in this study point to the need for integrated policy responses that address fire risk not merely as an emergency management problem, but as a product of unplanned urban growth, inadequate land-use regulation, and under-resourced municipal institutions (Kihila, 2017). Specifically, the spatial mismatch between fire risk concentration and station coverage, as demonstrated in the service area analysis, underscores the urgency of incorporating fire safety infrastructure into formal urban planning frameworks and municipal budgetary priorities. Therefore, enhancing fire management outcomes in Dar es Salaam requires addressing both physical and human-system elements, such as building design, occupant behavior, institutional capacity, organizational culture, and professional development.

STUDY LIMITATIONS

The socio-economic impact assessment is limited by incomplete data, lacking systematic records on injuries, property loss, displacement, and economic costs. This creates an evidence gap, restricting full burden estimation. Declining fatalities may reflect reporting changes, not only improved fire safety outcomes. Future research should seek to expand socio-economic impact assessment to include the full range of fire-related losses, validate spatial findings through longitudinal incident data beyond the 2016–2020 study period, and explore the operational feasibility of decentralized fire station models under local contextual and budgetary conditions.

CONCLUSION AND RECOMMENDATION

This study examined urban fire risk management in Dar es Salaam through the analysis of 2,119 fire incident records from 2016 to 2020, supplemented by spatial analysis, key informant interviews, and focus group discussions. The findings reveal several critical and empirically grounded challenges. Spatially, the Kernel Density Estimation analysis identified significant fire hotspot concentrations in high-density commercial and residential sectors, particularly within Ilala Municipal (n=603), while service area analysis confirmed that several high-density wards, most notably in Ubungo Municipality fall outside the 5-kilometre response distance threshold of any operational fire station. Operationally, the study documented a firefighter-to-resident ratio of 1:17,500, well below internationally referenced staffing guidance, and found that only 30 of 75 registered public hydrants are currently functional. Rescue success rates, as locally defined in this study, improved marginally from 4.3% in 2016/2017 to 13.2% in 2019/2020; however, these rates remain critically low, with Ubungo recording the lowest municipal success rate of 11.1%. These operational deficiencies are compounded by an urban spatial configuration constraints in which narrow, unplanned road networks severely constrain firefighting vehicle access, extending response times beyond acceptable thresholds. Assessing the feasibility of, and where appropriate implementing the decentralization of fire station distribution, budget allocation, and the presence of a digital spatial data management system may increase the department's capacity to respond to fire disasters in Dar es Salaam Region.

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