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Thesis title: Rhythm Analysis of Street Adaptability

Temporal and Spatial Dynamics in Informal Settlements for Enhanced Neighbourhood Adaptability

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Summary

This study investigates the adaptability of street design in Mathare, an informal settlement in Nairobi, Kenya, focusing on how spatial configurations influence the capacity to accommodate the evolving needs of residents. Employing a mixed-methods approach, the research combines ethnographic observation, key informant interviews, and focus group discussions to analyze the rhythms of activities across different street typologies.

The methodology involves intensive observation of what goes on in the streets for a span of three weeks taking into account temporal dimensions involved. Data collection employed various digital tools including, Kobo Collect application for gathering geolocation information as well as A-GPS application that takes pictures over certain intervals (time-lapse photography) to show how they change through space and time. The study explores a primary road Mau Mau Road and other narrower collector and tertiary streets in Math are to comprehend how adaptable they are based on their design.

Findings reveal distinct patterns of economic and social activities across different road hierarchies. Primary roads demonstrate the highest diversity and intensity of activities, with vending being the predominant economic activity, peaking during late afternoon and early evening periods. Social activities, particularly interpersonal communication, exhibit high intensity on primary roads, with peak periods in the afternoon. Collector roads display moderate adaptability, while tertiary roads show the least diverse activity patterns.

The research concludes that street design significantly influences the typology, intensity, and diversity of activities in informal settlement streets. Primary roads function as major economic and social nodes, collector roads serve as intermediate spaces, and tertiary roads primarily cater to local, and residential activities and are intimate spaces of social interaction.

Recommendations include primary roads having pedestrian accommodation expanded and flexible spaces that will best support the high-intensity activities surrounding them, while collector roads should have areas reserved for essential services, and tertiary roads should focus on pedestrian safety but allow some small-scale businesses. The study proposes using temporally based regulations to allow for participatory planning and design to enhance multi-functionality through purpose-driven community design in accordance with the needs of the people living there as well as promoting ownership.

This research contributes to literature on rhythm analysis, urban informality and street design, offering insights into the complex mix between spatial configuration and social-economic activities in resource-constrained urban environments.

Keywords: Street adaptability, informal settlements, urban morphology, rhythm analysis, mixed-methods research, spatial-temporal dynamics, participatory urban design

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EFL STICHTING

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Abbreviations

Abbreviation	Full form
IHS	Institute for Housing and Urban Development Studies
3iF	Integrated Inclusive Infrastructure Framework
CHP	Community Health Promoters
DURP	Department of Urban and Regional Planning
UoN	University of Nairobi

1 Chapter 1: Introduction

1.1 Motivation

Informal settlements are faced with several challenges that residents encounter daily. Limited resources, access to public spaces, inadequate infrastructure, and vulnerability to external shocks are just a few of the problems that these communities confront (Chirisa et al., 2020; Du Toit, 2009; Ehebrecht, 2014; Usamah et al., 2014). Despite these challenges, the streets in these settlements are more than just links; they are key elements through which various social, economic, and cultural engagements happen. The streets of informal settlements act as business centers, social interaction places, and venues that host events that are central to people's lives (Fachrudin, 2018). Another very important consideration in these areas is the ability of roads networks to handle change. They may be as a result of factors like rapid growth in population, shift in demography, arising environmental challenges or social-economic shifts (Du Toit, 2009; Ehebrecht, 2014). For instance, street corridors are required to expand their capacity to host more pedestrians, accommodate buying-selling activities, and allow room for emergency access during calamities.

The ability of streets to accommodate these changes is highly vital in enhancing the durability and well-being of the populace of the community (Usamah et al., 2014). However, there is a void in research touching on the adaptability of roads especially those that are in informal settlements. This study focuses mainly on the big picture of urban adaptability which tends to ignore intricate mechanisms and processes of street functioning and adaptations in these circumstances (Sun, 2022; Wen et al., 2020). It is crucial to understand these numerous and diverse factors to create tailored intervention strategies that would help enhance the quality of life and increase the susceptive groups' capacity to cope with and rebound from adversities.

This research seeks to fill this gap by looking into the chronology and the geography of a city's street use. Temporal variations are daily, weekly, and seasonal patterns of how the street is used. While, on the other hand, spatial dynamics are experimentation of various activities over the different street locations(Mulíček et al., 2015). A review of such factors can provide a good amount of insight regarding the ways, in which the design as well as management of streets could address the community's requirements and strengthen adaptability of these streets (Harsritanto, 2018; Shaaban et al., 2018).

This research adopts the concept of rhythm as identified by Lefebvre (2013), particularly rhythm analysis that defines the interplay between cyclical time, linear time, and spatial rhythms. If the method of rhythm analysis toward the investigation of street adaptability is used, it is possible to have rich understanding of the impacts of temporal and geographical aspects in studying informal settlements. It can reveal how streets can better adapt to changing conditions thus improving this part of the environment's capacity to sustain and adapt to different functionalities. Therefore, the main motive of this research is to offer a range of recommendations for reference in the formulation of urban planning and policies. Thus, the geographical and temporal specifics of informal settlements will be properly considered in the attempt to improve them. Thus, the enhancement of the adaptability of streets not only increases the value of streets but also improves the strengths of society such as social inclusion, economic prosperity, and community sustainability (Lotfata & Ataöv, 2020). This goes a long way in responding to emergent needs in the informal settlements of the urban fabric in today's society.

1.2 Locus and Focus of the Thesis

The subject of research for this thesis is the adaptability of the streets in informal settlements in urban areas and how the streets exist and react to different social, economic and environmental conditions. The study objectives are to identify how the temporal and spatial

cycles of life on the streets of such communities intertwine. This focus is important as streets in the informal settlements have other uses that are so vital and essential in enhancing residents lives.

This research focuses on Mathare, one of the largest informal settlements in Nairobi, Kenya (United Nations Human Settlements Programme, 2009). Thus, the area of Mathare was chosen as the study area because it has active street life that reflects various uses and activities characteristic of streets in an informal settlement. Mathare offers a setting that is characterised by; high population density, struggling socio-economic status and yet an ability to rebound. As classified by the (United Nations Human Settlements Programme, 2009), Mathare is an informal settlement having high population densities, less formal structures and limited-service delivery.

Having the study in Mathare Roads makes it possible to observe as to how streets can evolve to meet the demands accruing from the urbanization process, changes in socio-economic attributes, and environmental conditions. Therefore, the analysis of this particular area focuses on identifying the relevant problems and preferred solutions for Mathare. The adaptability of the street is one of the key qualities contributing to the improvement of communities and the awareness of this may improve the urban planning and policy-making.

1.3 Problem Statement

Informal settlements result from uncontrolled development caused by the housing deficit common in emerging and growing cities and are associated with several problems that affect the lives of occupants in different ways. These challenges include limited health, labour, financial, physical capital, poor infrastructure, and sensitivity to exogenous factors such as climate/natural disasters and business cycles (Chirisa et al., 2020; Du Toit, 2009; Usamah et al., 2014). Unfortunately, adaptability, particularly in reference to street production, is one important facet that is often disregarded in these settlements.

Streets in these settlements perform many vital and social functions apart from being mere channels for passing from one place to the other. Streets can be regarded as important social pillars that are inextricably related to business and cultural exchanges as well as social connectivity in the local context (Mbisso & Kalugila, 2018; The Hien Dang, 2018) . However, streets are not created to be flexible; hence, it poses inherent constraints within the context of change or dynamism in demand and other characteristics. The one that stands out is that street infrastructure maladaptation is likely to have several negative implications on informal settlement inhabitants' resilience and quality of life (Bettencourt & Marchio, 2023). In such dynamic conditions characterised by high population densities and constantly shifting demographic structure, streets have to be ready to adopt new activities and services. For example, a street created primarily for residents' households could gradually require additional functionality as small businesses or communal facilities to ensure better functionality (Von Schönfeld & Bertolini, 2017).

Moreover, life in informal settlements requires that roads have to be able to withstand the conditions of the terrain, as well as other forms of disturbances. They are mostly vulnerable to disasters influenced by floods, fires, and even economic downturns. Here, variable streets are necessary to change the land use for the requirements of minutes, for example, in the form of temporary shelter or the place for providing food and other essentials (Taş et al., 2013; Wekesa et al., 2011)

Streets play a crucial and an important role in enhancing the qualitative life of the people staying in the informal settlements. Proper planning of streets as well as their adaptability can lead to improvement in ways in which people can access fundamental facilities including

hospitals, schools, and clinics among others (Shekhar, 2020). They also cultivate an identity and a source of pride that is specific to a region's community, which in turn boosts the community's morale and proactively supports the people. However, there is a substantial research gap regarding the temporal and spatial heterogeneity within the informal settlements' street environment. In the current streams of literature, authors lack an understanding of the various aspects of complexity of the realities of streets and their possibilities for adaptation and survival (Gaisie et al., 2021). Such prospective studies will help to establish more detailed factors that have bearing on the subject of street adaptation.

This gap should filled in order to understand the nature and extent of needs that requires policy formulation to facilitate better strengths and coping mechanisms to foster the subject population's quality of life. This study endeavours to explore and explain the nature and pattern of temporal and spatial changes of streets to enhance the understanding of strategies to promote adaptability in an important component of informal settlements and, in the process, to inform the development of resilience and sustainability.

1.4 Research Question and Sub-Questions

1.4.1 Main Research Question

How does street design influence the adaptability of streets in Mathare to accommodate the evolving needs of the residents?

1.4.2 Sub-Questions

1. What are the **rhythms of activities** present in Mathare streets?
2. How does the **design of the street** influence the **rhythms of activities** that occur on the street?
3. What design principles or policy recommendations can be formulated to create adaptable and inclusive streets in informal settlements?

1.5 Structure and Reading Guide

The structure of this thesis is designed to systematically explore and address the research questions on street adaptability in Mathare. **Chapter 1** provides an introduction, consisting of the motivation for the study, the problem statement, the research questions, and an overview of the thesis structure. **Chapter 2** offers a comprehensive literature review, discussing existing research and the theoretical framework that underpins this study. **Chapter 3** outlines the methodology, detailing the research design, data collection methods, and analysis techniques employed in the study. **Chapter 4** presents the case study analysis, specifically focusing on the findings from Maumau Road in Mathare. **Chapter 5** is dedicated to the discussion, interpreting the results and their implications for both theory and practice. Finally, **Chapter 6** concludes the thesis by summarizing the key findings, highlighting the contributions of the research, and offering suggestions for future research directions.

2 Chapter 2: Literature Review

2.1 Arguments and Results from Existing Research

Informal settlements are mainly characterized by organic nature, random population increase and unplanned circumstances hence they hold poor infrastructure and services (Chirisa et al., 2020). Many of these settlements' characteristics of many regions in the Global South in the process of rapid urbanisation are poorly endowed, having no proper shelter and sanitation, little or no access to basic necessities such as education and health facilities (Ehebrecht, 2014).

Unfortunately, one cannot stress enough that one of the most important objects intrinsic to these pacts is the streets. Whereas in some other formally planned urban areas, streets may provide a single use, the situation in the study area is different. They are not only roads but also socially significance spaces which encompass social activities, business, and arts (Gaisie et al., 2021).

In these contexts, streets change into effective social arenas, where people can participate in several practices of the urban informal economy, for example, street selling and trading, what is crucial for survival. In addition, these streets transform into social areas in which people interact, children play, and cultures are celebrated to promote togetherness and citizens' identity within the community.(Mengistu & Jibat, 2015; The Hien Dang, 2018; Ulloa & Castillo, 2020)

Streets can transform themselves to fit the daily requirements as well as unforeseen disturbances. During disasters or similarly, during any economic difficulties, the capability of allowing streets to perform new roles, such as, for instance, shelters or the hubs for the provision of aid, is rather important. Despite the overwhelming prominence of streets' function, there are still many gaps in the understanding of temporal and spatial patterns of streets' use in informal settlements, as well as how these patterns enable them to adapt to their environments (Fachrudin, 2018; Kotani et al., 2020; Marshall, 2004).

It has been found that the design of streets in terms of spatial relations is a factor that has a decisive effect on the ways of using space and their changes. For example, road networks that are potentially usable for pedestrians and automobiles should allow various forms of activities and the presence of street vendors and other informal economic activities transform streets into a marketplace that actively contributes to the development of the economy and met the needs of residents (Fauzi & Aditianata, 2018; Ulloa & Castillo, 2020)

The functionality of streets is also affected by temporal dynamics. Another aspect that can be observed in streets is that activities staged are cyclical daily, weekly and seasonally. There are cases where some of the roads can only be used during the business hours, or perhaps more precisely, during the early morning when people are going to work and, in the evening, when they return home, while in the same time the same spaces can accommodate markets or social activities during daylight or on the weekends. Knowledge of these time-related characteristics is critical for designing interventions that would improve the level of street adaptability.(Fauzi & Aditianata, 2018; Kellerman, 1991)

The works by Lefebvre, particularly the construct of rhythm analysis, are useful in understanding temporal and spatial dynamics of these events. Rhythm analysis focuses on cyclical, linear and spatial rhythms, which means the cyclicality of daily routines, historical development and the usage of the space (Procházková, 2018). Rhythm analysis could be used to explore how people's lives are ordered through time and space in informal settlements, thereby witnessing how different street designs streets could be useful for inhabitants and improve community vulnerability. Consequently, the existing literature demonstrates that one cannot overestimate the significance of streets in the informal settlements because they perform

numerous functions in people's lives and contribute to community resilience. (Highmore, 2002)

2.2 Theoretical Underpinning

This research lies within the epistemology of the spatial sciences particularly, urban dynamics, resilience, and adaptability with reference to the multiple uses of streets in the informal sector. The theoretical framework consists of Lefebvre's rhythm analysis that deals with cyclic, linear and spatial rhythms. This framework enables a clear depiction of how the streets change at daily, weekly, and seasonal basis hence giving a full picture of informal settlements (Lefebvre, 2013).

In a broader sense, Adger (2000) posited that urban resilience refers to the system's capability to undergo disturbances and adaptation to maintain its primary function that has same structure and feedbacks at equilibrium. Thus, in the context of the informal settlements, resilience is defined as the capacity that allows the community to withstand various socio-economic and environmental shocks. Since Streets are parts of these settlements they support the effectiveness of resilience thorough mobility, economic functions, social interactions and emergency functions.

The multifunctionality of streets in the informal settlements is a core idea in this study, as suggested above. Those streets are not only pathways but are also places where numbers of activities take place. Such functions include economic, social and recreational, and cultural with references to being marketplaces, social interaction centers, play areas, and sites of cultural practice (Gaisie et al., 2021). This paper examines these multiple roles of streets and how they change over time and in response to external forces to come up with ways of increasing their resilience.

These dynamics seem to be effective to be studied through Lefebvre's theoretical concept of rhythm analysis. This framework of temporal construction divides cyclical time (daily/seasonal routines), linear time (history & development) and spatial time (space & functions) (Lefebvre, 2013). When applied to informal settlements, this modular scope enables the examination of how streets are used during certain times and how use is dependent on the structure of the settlement.

Cyclical time in informal settlements can be provided in form of daily and weekly cycles. For example, streets may experience traffic during the rush hours in the morning and in the evening, whereas the weekends may experience social economical activities like business markets and other social congregation. It also aids in developing interventions that are cycle congruent with the community – these are certain patterns in the community that help in creating interventions for handling social issues. (Kellerman, 1991; Udosen & Adam, 2009)

Linear temporal perspective entails approaching the identification of structure and functions of the liveable environment through analysing the history of the development of the settlement. In many cases, informal settlements are random and can develop organically, with streets adapting to the needs of the populations as and when it deems fit (Ehebrecht, 2014). A study of these historical changes gives understanding on how streets have evolved in the past and this can alert on possible future evolutions.

The temporal rhythms are the patterns of space which exist within the settlement and how they are utilized. This is in regard to the number of traffic lanes, sidewalks or not, and economic use zonation. Streets' usage changes according to their organization and the number of functions that can be performed in the street space. For instance, wider streets can be designed for both automobile and market stand while the narrower ones can only allow for pedestrian usage (Prelovskaya & Levashev, 2017; Udosen & Adam, 2009)

Street Design as an Independent Variable

The layout of streets determines the performance and flexibility of the public realm in cities, especially the informal ones. Street design refers to a plan of streets, which include factors like, width of the streets, how they are inter-connected, and whether pedestrian pathways and or public places are incorporated in the designs, street design factors impact social, economic and the resulting environmental realm in the society (Marshall & Garrick, 2010). Well-designed streets create effective connectivity, promote economic activities, and enable symbolic interactions and thus, increasing urban resilience.

Streets in informal settlements are naturally formed hence creating a weak basic infrastructure and facilities. They result in overcrowding and restricted accessibility to services and also exposes the surrounding environment to various (Aboulnaga et al., 2021). However, research suggests that even in similar environments, there is the capability of achieving an appreciation of the street functionality and flexibility through effective street design (Mathiba, 2019). Thus, broadening of the pathways, creation of pedestrian areas and incorporation of the multifunctional public spaces can turn streets into the lively activity centers of the communities.

Dependent Variable: Street Adaptability

The term street adaptability relates to the characteristic of the street infrastructure to adapt to the new trends and emergent conditions. Such flexibility is essential in the context of the growing population of the informal settlements since such areas are characterized by social and economic dynamics. Street adaptability is comprised of two sub-variables: The two organizations' structures emphasize flexibility, including multifunctionality and multiple rhythms. (Harsritanto, 2018; Siu & Wong, 2015)

Multifunctionality

Functional versatility relates to the ability of streets to accommodate various activities and functions at one and the same time. Streets in the informal settlements are not solely transport facilities but also areas of business activities, social interaction, and cultural events (Hidayati et al., 2021). The versatility of streets can aid the improvement of community resistance by offering grounds for economic activities and social meetings, consequently undergoing the quality of life.

For example, Dovey et al., (2020) denote that it will be easier for multifunctional streets to adjust to certain situations or states. For instance, the streets that are provided for markets may be able to accommodate changing patterns of economic activities, while the same can be the case for social related activities such as celebrations and other functions because of the-way present day streets are designed (Fachrudin, 2018). Hence, enhancing the adaptability of streets, the function of their design lies in the fact that it should be multifunctional.(LaPlante & McCann, 2008)

Multiple Rhythms

Multiple rhythms pertain to the temporal organization and periodicities of the use of streets, namely daily, weekly and seasonal. Hewidy & Lilius, (2022) stress the diffused and synchronization of rhythms and cycles that are linear as vital in making sense of the urban. As far as the rhythms of streets are concerned, they go through various changes according to the variation in social factors like working hours, days of market and any kind of cultural programs (Gaisie et al., 2021).

These are the rhythms of roads which are important to be understood to create changeable streets adequately. For example, streets frequently used by pedestrians especially during market

days must be open to serve other purposes besides the hustle and bustle of market days yet be functional at the same time as pointed out by (Aboulnaga et al., 2021). In a similar manner, fluctuations in density, for instance, coming of many people onto the streets during the festive season, require streets that adapt to these densities. Including varied rhythms into the street layout makes the street functional and valuable at any one time and under different circumstances.

2.3 Temporal Rhythms

Temporal rhythms refer to temporal organization of activities in the settlement achieved by cyclic processes of various time scales (Häfker et al., 2023). Examples of these are cyclical activities that occur within 24 hours of the day, activities and changes that occur within a week and activities changes that occur depending on the season. It is important to establish these temporal patterns because they define the ways and timing through which a street is utilised. For example, streets could be avenues of commerce during the day, but stretching space to socialize at night. Streets may require adaptability at some periods of a particular year, for instance, the same way festivals require roads' adjustment or access that becomes more familiar because of favourable weather conditions (Kellerman, 1991; Su et al., 2022).

2.3.1 Influences on Temporal Rhythms:

2.3.1.1 Daily Activities:

Rhythmicality within the informal settlements can be conceptualized in the following ways; Tempo is created through different factors that affect the use of the street space at different times. These are aspects that denote temporal characteristics of streets basically in terms of daily activities including work patterns. In weekdays, most of the traffic is observed in mornings and late evenings when people are going to work or returning back home. Day-traffic vendors start their business early in the morning to target working population, while night activity may also get a boost from the returning residents. More often, evenings and weekends attract ample social activities since streets become common grounds for social functions, recreation, and children's playgrounds. (Qi et al., 2015)

2.3.1.2 Weekly Cycles

Weekly cycles also affect the usage of streets. Weekdays and weekends have different characteristics and duties where weekdays are business-oriented and filled with particular tasks connected with job or studies. Weekends, on the other hand, are generally less busy with increased probabilities of socialization and communal activities. Chronologically limited occasions for market, when people gather on certain days of the week, are one of the causes of flit of street usage (Ladd, 2020). Streets are invaded with vendors and people transacting their businesses or in search of various items hence causing disruption of the normal flow of traffic and changed street patterns during these days.

2.3.1.3 Seasonal Changes:

Climate conditions and especially deviation in the climatic conditions affect street usage. In the rainy season, there are likely to be some streets that become impassable affecting daily activities and may be solved through use of temporary structures or fashioning out of another way (Taverner, 2022). In the same manner, reference point temporal components include seasonal festivals and cultural events which also help to define rhythms of streets. It requires the transformation of streets into avenues that can contain high number of people, stages and other business selling items, which changes the essence of streets briefly. (Khalid et al., 2019)

2.4 Spatial Rhythms

Spatial rhythms pertain to the physical and functional organization of activities across different areas of the streets. This includes the distribution of economic activities, social spaces, and

residential areas. The spatial configuration of streets influences how effectively they can accommodate multiple functions and adapt to changing needs (Bindajam & Mallick, 2020).

2.4.1 Influences on Spatial Rhythms:

2.4.1.1 Physical Layout:

The shape or physical configuration and connections of streets are very significant to the performance and adaptability of streets. Wide streets have more potential to allow several functions at the same time, for instance, traffic, walking, and trading (Wen et al., 2020). This supports the street life effectively and makes it rather easy for the various uses to integrate into the same general area without much conflict. On the other hand, narrow streets are usually limited to certain purposes mainly accommodating functions that give priority to pedestrians and contain predominantly small businesses. Streets establish connections and organize the arrangement of the settlement in such a way that the residents, objects and activities can easily interact with each other, literally, move around the streets without much difficulty (Ehebrecht, 2014). High connectivity also entails better disaster responses and services where all parts of the establishment can be reached in emergencies.

2.4.1.2 Infrastructure and Amenities

Existence of infrastructure facilities like sidewalks/edges, street lighting, and other public facilities make the streets more functional and safer. Concerning the quality, good infrastructure contributes to multi-functionality and improved general robustness of the street space (Shaaban et al., 2018; Sheikh-Mohammad-Zadeh et al., 2022). The sidewalks serve as walkways for pedestrian, Street light enhances the safety of the streets and the hours of usage, rest rooms prepare the users /Occupants of the street space for longer use of the street space. Infrastructure such as health facilities, schools, and sanitation contribute greatly to street use since well-developed streets for such purposes are likely to be more active and included into the users' daily routine .This integration assists in the development of a complex and robust street environment, thereby promoting the adaptability of the space and its ability to accommodate many aspects of the community's daily life and life events. (Harsritanto, 2018; Shi & Ren, 2019)

2.5 Social Dynamics

The social aspect includes the roles and connections of the society in the processes that affect and exploit street scenes. Such dynamics mean a lot within the course of usage of streets and within the context of possible functional transformations. The patterns of the people from the community, beliefs and governance practices in the community and structure of power determine the beats and patterns of social life in the streets and carry forward the strength of the neighbourhood. (Human, 2016; Leyzerova & Bagina, 2018)

2.5.1 Influences on Social Dynamics:

It asserts that street spaces are highly significant as they are prime social interaction facilities where people carry out their daily business and social activities among other things. The frequency and kind of such interaction nurtures togetherness as well as interconnection in response to proper social relations and collective stability (Mamaghani et al., 2015). Neighbourhood huddles and festivity are other important ways which facilitate interaction of individuals and consequently facilitates the exchange of resources and information. Therefore, the presence of streets in the community helps in the provision of physical spaces that enhance social network among the people. Positive relations between people in the community make information and resource sharing within the community profound, leading to community responsiveness (Banwo et al., 2022). For instance, the informal markets on streets are economically oriented but at the same time, social relations between the sellers and buyers are

improved. These networks can alert people in moments of disaster and connive resources and agitate for better provision of services and features.

Patterns and practices of the community greatly determine how the space of the street is utilized and appreciated in the context of I participatory slums. Thus, the cultural activities, festivals, and other social events including religious ceremonies usually happen at the streets to affirm the primary functions of the streets as social (Shaw, 2020). Besides preserving cultural status, such activities also contribute to the stimulation of the communities' unity and identity. Culture plays an important role in determining the proper use of street spaces depending on the evolution of their functions through time (Swartjes & Berkers, 2022). A road that contains weekly markets may have cultural significance and is cherished and provided for to meet different functions.

It is imperative to study and include these social processes into the formation of urban planning and policies to increase the stability of informal urban settlements. When decision-makers and strategists underscore the significance of people's community interactions, social networks, and cultural practices, it is possible that streets would be designed as well as resources would be allocated to reinforce those positive aspects. It enhances social cohesion through increased collaboration in the management of resources and enforcement of actions that boost the robustness and adaptability of the ghettos (Abbott, 2002; Elrayies, 2016)

2.6 Multifunctionality of Streets

Therefore, it can be observed that the connection between temporal rhythms, spatial rhythms, and social dynamics leads to the formation of multiple functions of streets. The streets of the informal households are used for marketing, social and playing activities as well as routes of daily traffic (Adebara et al., 2022). This versatility is one of the strongpoints of these systems and the reason why they proved immune to the crisis. Given ability of streets to accommodate all these functions ensures that they remain and integral part of the city's structure, with the ability to adapt to different socio-economic and environmental forces. (Al Faraby, 2021; Salvo et al., 2018)

2.6.1 Multifunctional Uses of Streets:

Roads in the informal settlements perform multi-faceted roles that play crucial roles in the disaster risk reduction and health of a nation's population. They act as business centres that accommodate business people for trading purposes that create employment for business people and ensure that consumers have a definite place to access goods that they need for their day to day lives (Karunarathne & Lee, 2020). These marketplaces pay their way in the economics of the community since they continue to be profitable regardless of shake-ups in the economic structure. Streets also serves as a meeting point in people's interaction with their peers; with publicly shared communal functions as well. These interactions provide the much needed sense of belonging in the society hence promoting social cohesiveness and capacity to handle adversity (Houshyar & Abdollahpouri, 2013). Street parties during cultural or religious festivities contribute to members' social interaction and cultural/symbolic identity hence the relevance of a street within the cultural context of the settlement.

2.6.2 Enhancing adaptability through Multifunctionality:

In this context, the versatility of streets contributes to the general ability to improve adaptability in several aspects. This aspect makes it possible to easily change the use of the space since one can convert a street into a gathering area for cultural events or community meetings without major changes(Mahboubeh et al., 2011; Montella et al., 2022). Thus, multifunctional streets are also vital in emergencies, such as delivering food or providing shelter through the distribution of materials or the construction of improvised structures. Furthermore, pedestrian

streets and other street types play an even greater role in enhancing people's quality of life in the informal settlements as they allow for economic, social and recreational activities (Oviedo et al., 2021). As a result of these functionalities of the local environments, they contribute towards promoting the social and economic standards of the residents thus boosting on their stability and health.

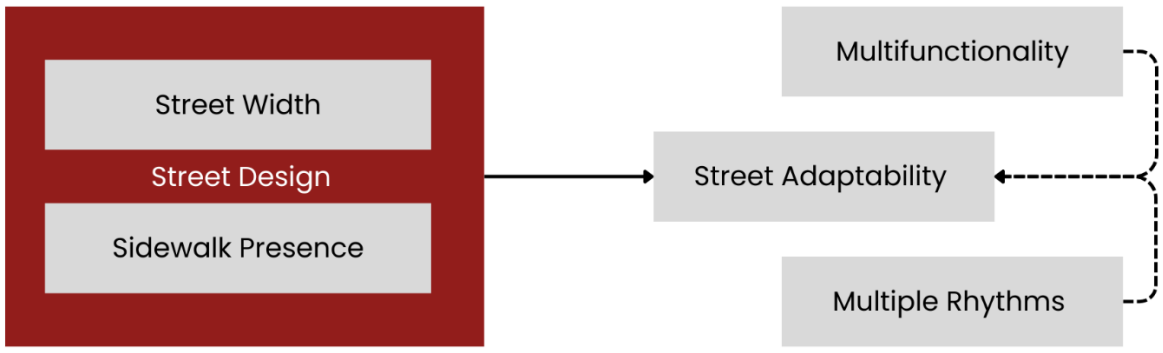
2.7 Association between Street Design and Street Adaptability

There exist a relation between the street layout and the capability of a street to adapt to changing use in the urban literature. The effective street design is the multifunctional and multi-rhythm design, which raises the flat adaptability (Marshall & Garrick, 2010). For instance, where streets are broad with pedestrian lanes and where markets are conducted; it is easy to convert the same from a market area to a social congregation area and vice versa (Gehl, 2011). Research by Lee & Bencekri, (2021) reveals that the streets in the informal settlements that can accommodate the changed use and multifunctionality can enhance the community's resilience. Streets are therefore able to play significant roles in the social and economic fronts since they can adapt to the changing activities and demands of users.

2.8 Implications for Urban Planning and Policy

To advance multifunctionality, the urban planning policies should pay attention to the adaptability of the streets within the context of the informal settlements. This calls for the use of integrative planning strategies that include and acknowledge the multiple functions of streets. It means that by bringing the champion and the many-sided demands of residents, it is possible to create the streets properly serving as actual communication and common venues and reflecting their multiple functions and prerequisites in their usage and creation if necessary. (Ding & Yao, 2014; Sheikh-Mohammad-Zadeh et al., 2022)

Another element in the planning of cities is the adaptability of the infrastructure. Adaptability is one of the major features that should be considered in infrastructure because it should be evident how easily they have to change according to the particular needs and conditions. For instance, streets can be doubled up as the roadway and social planes, with the ability to adapt to happenings in the society or changing needs in terms of time. Such adaptability allows for the proper functioning of streets primarily for the reception of emergencies, the economy, and social relations. (Al-Saaidy, 2020; Ding & Yao, 2014)



3 Chapter 3: Research design, Methodology

The methodology for this research on rhythm analysis of street adaptability in Mathare, was designed to capture the complex dynamics of urban street life in an informal settlement. The research study used a case study approach, focusing on several streets within the settlement, including the major street Mau Mau Road and other smaller streets with varying widths. This selection enabled the comprehensive examination of how different street designs influence adaptability across different contexts.

The primary research question guiding this study that informed the selection and crafting of this methodology was: "How does street design influence the adaptability of streets in Mathare to accommodate the evolving needs of the residents?" To address this question, a multi-method approach was adopted, combining the observational method with key informant interviews and focus group discussions, complemented by digital tools used for capturing spatial and temporal dynamics.

3.1 Mixed Methods Design:

The research employed a Multiple case study design where different roads within mathare were studied to observe the changes that occurs. Combined with a mixed methods data collection approach was used (Rashid et al., 2019). Qualitative data collection used to identify and map the recurring patterns of activities that occur on Mathare's streets at different times. In this ethnographic observation, detailed field notes were used capturing changes throughout the day for three different days between 6 am to 10 pm for the different street typologies. Descriptive analysis was used to categorize and describe these activities and identify patterns and their influence on street use. Documentation of the dynamic nature and movement pattern was done using time lapse photography. Another technique that was applied was the mapping of space which depicted the locations of activeness during the specific periods of the study.

The type of observational study method that was employed was deemed appropriate because of its ability to capture naturalistic data on streets' functioning and flexibility. The observation had both a formal and an informal structure to it (Lofland et al., 2022). This led to the creation of structured observation checklists to document specific data on the number of variables for aspects like the intensity of activity, businesses that are in the area, street furnishings, and people's interactions. These checklists helped in easing check and crosscheck from one observation period to the other or from one location to another. The use of documented observation was equally important since the researcher had to freewheeling/casual in the observation of the days' unfolding so as to able catch these structures that define street adaptability. Field notes were kept to document such observations besides other structured data that were collected during the field study. (Khalid et al., 2019)

In this study, the observation schedule that was used was well-developed, elaborately planned and accurate. Observations were conducted during both weekdays and weekends. The time that was chosen started from 06:00 AM and ended at 10:00 PM so as to reflect the entire spectrum of activities. It enabled the researcher to observe activities of residents going to work in the morning, mid-morning business and market activities and evening social activities. The period of the research also posed a challenge since the study area was also endowed with unique activities that are not a regular, such as the disastrous floods and the government's demolitions of structures within the riparian zones. This made it possible to examine streets' adaptability on these particular circumstances.

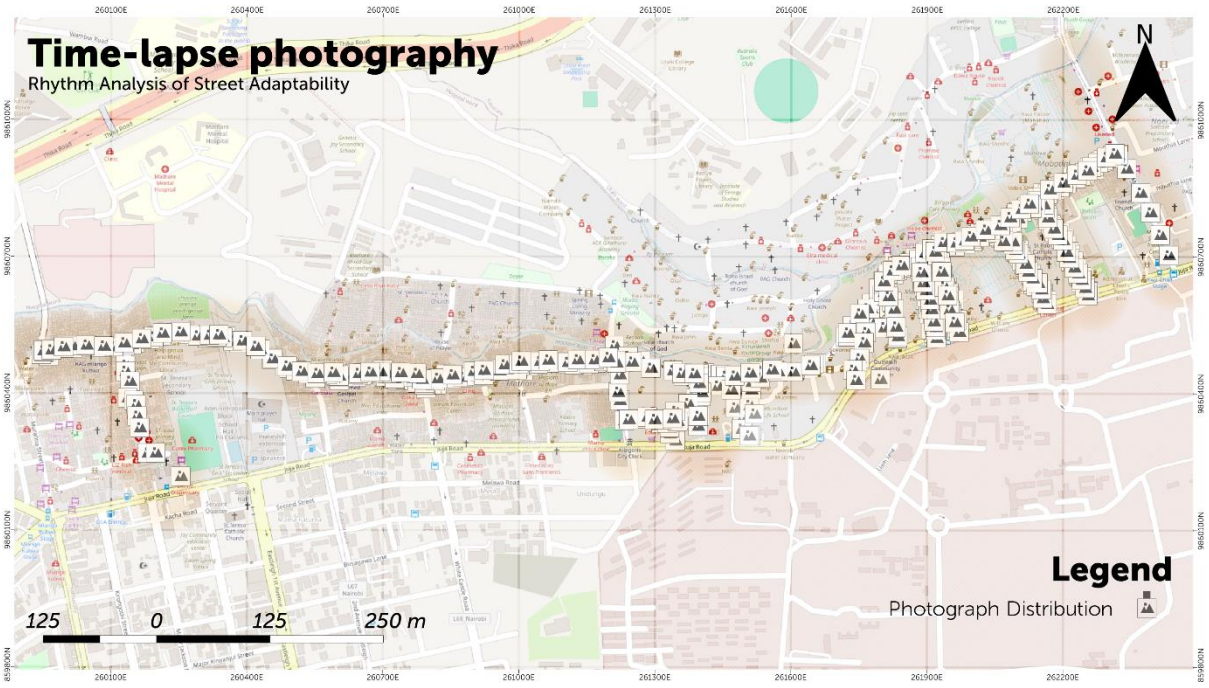
3.2 Data Collection

To ensure the safety of researchers and the accuracy of data collection, especially during the volatile periods, three local research assistants were employed. Their familiarity with the area was invaluable, particularly during tense periods when floods threatened homes or when government officials conducted demolitions. Their presence did not feel as if it was a non-resident spying on the activities of the people with the increased tensions of demolitions. The presence of the research assistants also assisted in reducing the observer bias because they hardly attracted the natives' attention. On the same note, their experience with the roads coupled with the fact that they were probably local made it easier for them to manoeuvre to and from the different areas.

The evaluation of the street life incorporated both technological instrumental approaches coupled with conventional observational techniques. The Kobo Collect app also became the notebook where researchers could indicate the accurate places, types, intensity and even photos of the activities. This tool put measures in place to see that data collected was accurate and also assisted in the collection of geolocation data, which was greatly useful in the analysis stage.

A-GPS app was employed to map out entire streets, capturing the flow of movement and the changing character of spaces throughout the day through photographs as shown in the map Map 1. This meant that one had to traverse from one end of the street to the other, which should ideally take one hour per street in order to capture all that the experience of the street entails. It recorded basic paths and brought snapshots at regular intervals and the general demeanour of the streets.

Map 1:Time Lapse Photography



(Source Research, 2024)

3.2.1 Interviews and Focus Group Discussions

To supplement the result of the observation, integrated interviews were conducted with key informants who comprised of the local village heads *(Nyumba Kumi)*, some of the urban planners involved in the informal settlement upgrading projects, and professors in the University of Nairobi, from the Department of Planning. These interviews offered some additional information about the general context of urbanism and development processes in the

informal settlements and the difficulties and possibilities for the improvement of the street versatility in such areas.

Meetings were arranged as participants from different demographics of the community were called upon to discuss in focus groups. The respondents were composed of the CHP, village heads, business people and employers, church leaders, and young footballer coaches. These discussions constituted elaborate discussions of the interactive problem-solving debates concerning the activities that occurred in the streets, ideas for the development of the multifunctional areas, and people's memories of how the corresponding corners had always been inhabited by people and had always been the habitation of generations. The extent to which the proposed ideas of street adaptability are perceived by the community and what kinds of adaptation they see themselves in the future were investigated using the focus group discussion.

3.3 Sampling Method

Two Sampling methods were used to arrive at the 2 main tenents of the study Purposive Sampling and Random Sampling. Purposive sampling was used in the identification of streets to be studied in order to get a wide cross-sectional sample of the urban settings. For the investigation of multiple streets, a number of streets were chosen, and each street was observed comprehensively. Random sampling was used to identify the different times to record findings with an interval of 20 minutes. This was done through a Python code attached in Annex 4 and was done for one day as it proved not to capture the entire street stretch. The other days involved walking along the streets observing and taking geo tagged photos. The streets identified for observation were Mau Mau Road being that it is a wide road where many people move on foot and business activities are carried out. Smaller Streets having different widths of streets like 8 meters, 6 meters, 4 meters and 2 meters to observe the effect of width in designing of streets on its flexibility. The 8 and 6-meter roads were categorized as collector roads and the 4 meters and 2-meter roads were categorized as tertiary roads. The use of this sampling method was in line with the study and ensured that the streets were well-distributed according to typology and experience on the streets of Mathare.

3.4 Time Frame:

Street activities were captured for three weeks to capture temporal variation. Data was collected during varying periods of the day, that is; morning, afternoon, and evening time, and different days of the week; weekdays and weekends. In this way, the study enabled the researcher to document both, the day-to-day changes in street activities and cycles of flexibility.

3.5 Operationalization of Concepts:

To ensure clarity and consistency in data collection and analysis, key concepts were operationalized: To ensure clarity and consistency in data collection and analysis, key concepts were operationalized:

1. Rhythms of Activities: This was done on the basis of the distribution and intensity of activities that the researcher was able to record (for instance markets, people walking, celebrations) at certain parts of the day.
2. Street Design: This also referred to aspects related to physical dimensions channelizing street include width, the existence of street furniture and condition of the pavement.
3. Adaptability Indicators: Streets' flexibility to perform multiple roles and meet the needs of a city was evaluated based on changes noticed over time and from the perceptions of stakeholders.

3.6 Operationalization of Key Concepts:

Concept	Conceptual Definition	Operational Definition	Dimensions	Indicators
Street Design	The physical layout and elements of a street influence its function and usability (Rahman et al., 2018).	The observable qualities of a street that determine its ability to accommodate various activities.	- Street Elements: street width, vending, or play. (Gehl, 2010)	- Width of road. - Presence and size of designated areas. (The carriageway and any other space on the road)
Adaptability of Street	The capacity of a street to accommodate a variety of activities and adjust to changing needs over time. (Rauws & De Roo, 2016; Yu, 2022)	The measurable characteristics of a street that allow it to accommodate different activities and changing patterns.	- **Multifunctionality**: The ability of a street to support a wide range of activities throughout the day. (Al Faraby, 2021; Salvo et al., 2018)	- **Diversity of Activity Types**: Number and variety of observed activities.
			- **Spatiotemporal Rhythms**: The recurring patterns of activity that change based on location and time. (Lefebvre, 2013)	- **Activity Distribution**: Spatial distribution of activities across the street and temporal distribution throughout the day/week.

3.7 Data Sources:

The study relied on both primary and secondary data sources. The Primary Data as collected through Participant observations, interviews and focus group discussions which were carried out by the researcher and community research assistants. Secondary Data was obtained from local government reports and community opinions were employed in order to get more details and corroborate observational data.

3.8 Qualitative Analysis

The subsequent method used was comparative analysis to analyze the field notes, photographs interviews and focus group discussion data. The process analyzed street design factors that affect the capacity to adapt to the streets in Mathare. Photographs and field notes were also analysed in a content analysis to review the recorded gather, sort, and analyze data according to the identified and developed categories.

Content analysis was also conducted on, the 682 geotagged, photos taken and field notes to systematically review, categorize, and code data based on predefined and emergent themes. Activities on the photographs were categorised into 3 broad activity types (Economic, Social and Transportation) with each having a specific activity given an intensity rating of 1 – 5.

3.9 Validity and Reliability Measures:

Several measures were taken to ensure the validity and reliability of the research. Triangulation was done by the use of observations, interviews and focus group discussions to increase its validity since all the data collected were supplemented with the other in giving a more wholesome understanding. In order to ensure internal validity, observation protocols were used and were equally adhered to across all the case study areas. Information and preliminary interpretations were discussed with people from the community to establish the validity of the interpretations.

3.10 Ethical Considerations:

The research team was acutely aware of their responsibilities as researchers and took several steps to ensure ethical conduct: The research team was acutely aware of their responsibilities as researchers and took several steps to ensure ethical conduct. Observations took place in areas where people have relatively limited reasonable expectations of privacy and every possible attempt was made not to collect any information with identifying people without their consent. To ensure the focus group participants' anonymity they were not photographed in a way that their identity could easily be determined. The papers and photographs taken when conducting the fieldwork were kept in a way that they could not be accessed by unauthorized people. Measures were taken to ensure participants' identities were masked before and during data collection. Researchers remained aware of and sensitive to the cultural context of Mathare, always ensuring respectful and appropriate conduct. The observational methods were designed to be non-intrusive and respectful of the street users' activities and privacy.

3.11 Limitations and Challenges:

The research team acknowledged several limitations and challenges:

Scope of Study: The focus on a limited number of streets only in Mathare may limit the generalizability of findings to other urban contexts. Temporal Constraints: The three-week observation period, while intensive, could only capture a snapshot of life in Mathare. Longer-term trends in street adaptability may not be fully reflected. But the focus group discussion was used to try ensure the validity since the questions asked were on the happenings along the streets over different periods of time in the year. Weather and Unforeseen Events: Weather

conditions and unforeseen events (such as political rallies and community events) affected the data collection process and introduced variability that is difficult to control. Language Barriers: While researchers were fluent in the local languages, some nuances in communication during interviews and focus groups may have been lost in translation.

3.12 Data Management:

A data management plan was used to ensure the integrity and security of collected data for instance detailed and structured field notes were maintained to capture all relevant observations systematically. These were digitized daily to prevent loss of information. Photographs and digital data collected through Kobo Collect and A-GPS apps were stored in a secure, cloud-based system with regular backups daily at the end of data collection. All interviews and focus group discussions were recorded (with permission) and transcribed. The original recordings were securely stored and will be deleted after 2 2-year period. All the data was further stored on password-protected devices, with access restricted to only the researcher. The data collected by the research assistants was deleted from their devices immediately after submission and backup.

3.13 Interpretation and Reporting Plan:

A detailed narrative is used to present the findings, supported by direct quotes from field notes and illustrative photographs collected in the study. Maps, diagrams, and infographics are created to visually represent spatial patterns and temporal rhythms observed in the streets. Findings from different street typologies were compared to highlight how design features influence adaptability. Contextual Interpretation: Findings were interpreted in the context of existing literature on urban street adaptability, highlighting both congruences and discrepancies. Policy Implications: The implications of the findings for urban planning and policy are discussed, with recommendations for enhancing street adaptability based on observed patterns. Plans are made to share findings with the community through local meetings and workshops, ensuring that the research benefits those who participated in it.

4 Chapter 4: Results, Analysis, and Discussion

4.1 Background

Mathare, often referred to as Mathare Valley, is an extensive informal settlement located approximately three kilometers northeast of Nairobi's central business district (CBD). Encompassing around 73 hectares, Mathare stands as the second-largest informal settlement in Kenya after Kibera.

Mathare is divided into 13 distinct villages, which serve as units for data analysis and community organization: Gitathuru, Kiamutisya, Kosovo, Kwa Kariuki, Mabatini, Mashimoni, Mathare 3A, Mathare 3B, Mathare 3C, Mathare 4A, Mathare 4B, Mathare No. 10, and Village 2. Each village has its unique characteristics and challenges but collectively, they contribute to the diverse and dynamic nature of Mathare as a whole.

The history of Mathare dates back to the early 1920s, following the displacement of residents from the nearby Pangani area. Initially, unauthorized settlements emerged on land leased from Asian landlords, primarily used for quarrying rocks to supply building materials for Nairobi's growing urban infrastructure. This early settlement pattern laid the foundation for Mathare's development as a hub for informal housing and economic activity (Etherton, 1971).

4.2 Road Design

4.2.1 Description of Road Types

Mathare is composed of many individual elements, and each presents their own character developed by physical conditions such as space and functions that the streets hold. These sections are very different in physical planning, and this is probably because this is an informal settlement that is full of dynamism and richness.The streets observed ranged from a minimum of 2 m to a maximum of 20 m. This as obtained from the photographs and the observation in the study area.

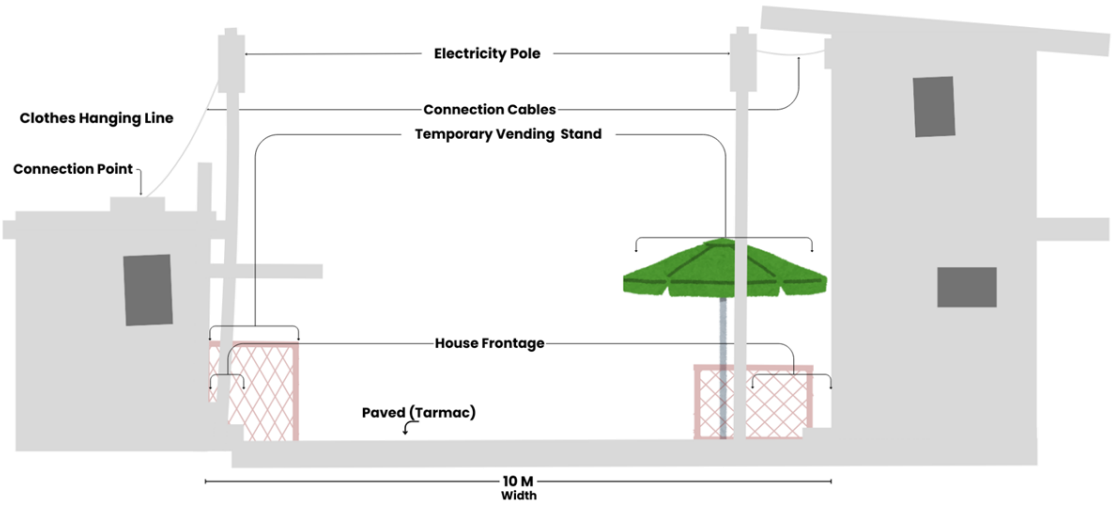
Map 2:Observed Streets Width

(Source Research, 2024)

Primary Roads: Characteristics and typical uses

These are broad roads in contrast to the narrow ones with the width of these roads ranging from eight to ten meters. One of the best illustrations of this is Mau Mau Road which is a partially tarmacked road that forms the lifeline of the sectors of the settlement. It has adequate potential to handle more traffic including both cars and pedestrians without many difficulties. The markets usually integrate spaces for selling and other economic opportunities leading to vibrant streets of trade and sociability. However, the surface of Maumau road is not tarmac throughout with several sections in a poor state of repair raising the prospect of reduced functionality at some points.

Figure 1:Primary Road Cross section

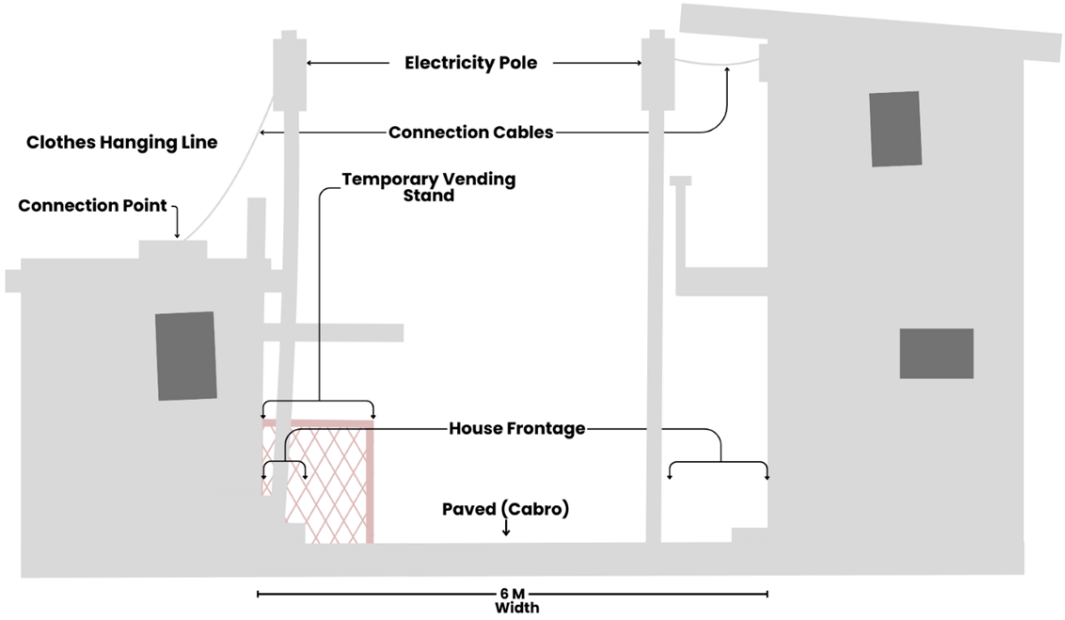


Source: Researchers Sketch on Street Cross-section, 2024

Secondary Roads

Pavement with slightly wider access roads of about 4 meters wide are important link roads connecting the important arteries that run through Mathare. These connecting streets bear a lot of importance when it comes to the transportation of people and commodities within the settlement. Most of these streets have some level of paving which may include cabro blocks and locally improvised structures paving, they are normally characterized by poor or limited physical work. To make the area easily accessible some of the roads have been worked on by the government to improve their surface to enable ease of manoeuvring around the settlement and described by one respondent in the focus group discussion. Figure 2 shows an example of the cross section of the collector roads withing the settlement

Figure 2: Collector Road Cross section

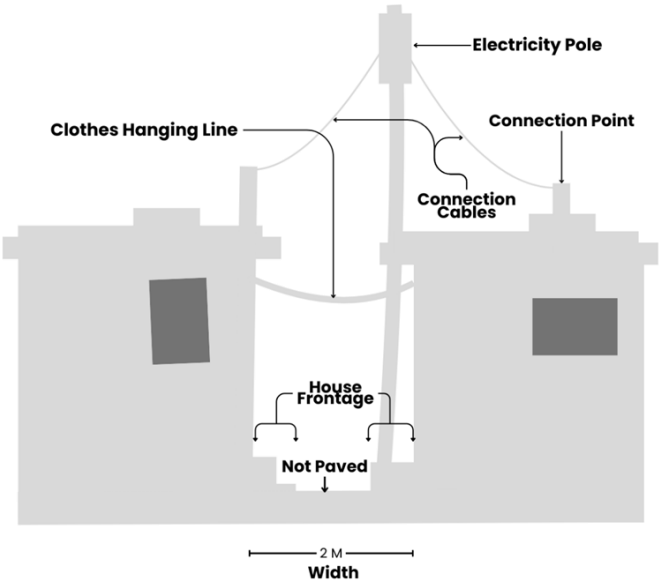


Source: Researchers Sketch on Street Cross-section, 2024

Tertiary Roads

The living spaces in Mathare are connected by narrow corridors which are usually about two meters wide at most these form the tertiary roads in the settlement wich are locally known as *Choches* from the description of participants in the focus group discussion. The space is confined entirely to pedestrians, and the movement of vehicles is impossible in these sections because of the narrow width. There is a feeling of segregation due to the closeness of structures on the two sides; the Informal manner of construction presents a problem of being in bad condition when there is heavy rain. Although the primary purpose of such narrow streets is to serve as residential access corridors, these lanes may sometimes have a few small traders' shops or temporary stalls to give a pinch of commerce on this generally residential access environment.

Figure 3: Tertiary Road Cross section



Source: Researchers Sketch on Street Crossection, 2024

4.3 Road Adaptability: Multifunctionality and Rhythms

4.3.1 Multifunctionality

Roads in Mathare serve different purposes as they support a different range of economic, social, and transport activities within the day. Economically, the roads serve as areas of commerce, with vending being the most eminent activity. Vending from structures (18.83%) was observed to be the most dominant, then followed by roadside vending (2.28%) and vending on carts (1.02%). Other important economic activities noted included garbage works (1.76%), motorbike stands (1.76%), and firewood selling (1.31%). Small-scale industries such as carpentry (0.34%), metal fabrication (0.28%), and scrap metal collection (0.34%) also take place within the streets of Mathare adding to the local economy's growth.

Photograph 1:Vending Activities

Source : Mathare research Observation, 2024

Socially, streets were observed to serve as community spaces. People were observed to be conversing along the streets (6.37%) highlighting this as the most common social activity, followed by residents relaxing (3.30%) and children playing (2.73%). Other activities like fetching water (2.84%), washing and drying clothes (1.71% and 1.54% respectively) and washing utensils (0.51%) were also observed to take place along the streets. These activities highlight the streets' importance in facilitating social interactions and daily chores. Another peculiar activity witnessed was fundraising along the street as shown in Photograph 2 and 3 bringing out this aspect.

Photograph 3: Tent set up along the road for fundraising

Photograph 3:Stool Set up along the street to collect funds

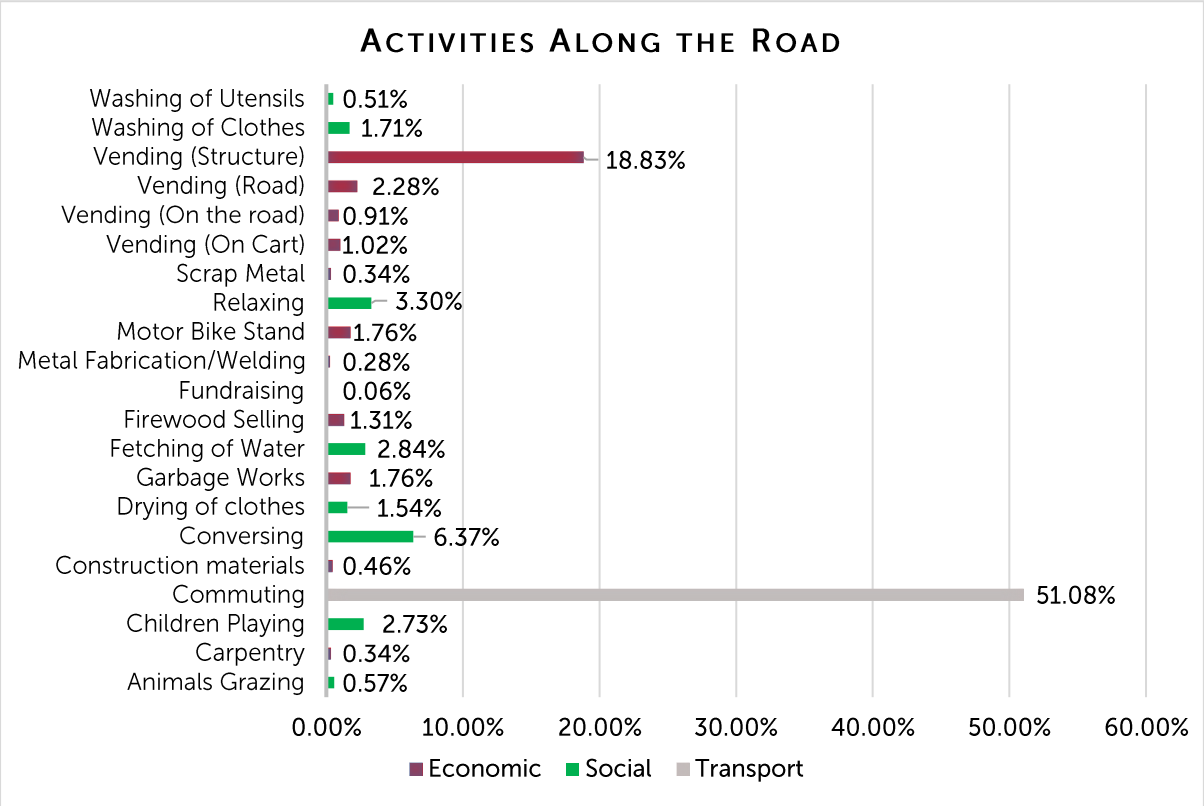
Source : Mathare research Observation, 2024

Transport was observed as the primary activity, accounting for 51.08% of road usage. This high percentage clearly shows the important and main role streets play in facilitating daily movement for work, education, and other purposes in Mathare

Photograph 4: Transport along the road

Source : Mathare research Observation, 2024

Figure 4: Activity Distribution Along the Road



Source: Mathare research Observation, 2024

4.3.2 Rhythms of Activities

Observations from the economic activities along streets in Mathare show a differing pattern throughout the day. The different activities depict different realities. Carpentry peaks were seen to start at 10 AM with an intensity of 2.3 maintaining that intensity until 2 PM. Construction materials were also observed along the roads in Mathare mainly spanning from 10 AM when construction workers working in housing improvement within the settlement begin and also are intense in the evening when the construction materials are being dropped in the area. Garbage-related activities remain consistently high at 9 AM, 10 AM, 1 PM, and 7 PM, all with an intensity of 3. Firewood selling reaches its peak at 2 PM with an intensity of 3.22, while maintaining consistent activity throughout the day.

Vending activities also vary based on their type and location. Cart vending peaks at 5 PM with an intensity of 3.25 this mainly showing a pattern of high intensity in the evening, while road vending is most intense at 2 PM and 7 PM, with intensities of 3.2 and 3 respectively. Vending from structures reaches its highest point at 4 PM with an intensity of 4 and remains high until 7 PM.

Social activities also demonstrate particular patterns. Children playing peaks at 5 PM with an intensity of 3.5 and remains active until 6 PM an explanation of times after school. Conversing is most intense at 4 PM with a level of 5, followed by significant activity at 6 PM (3.5). Clothes drying reaches its peak at 2 PM with an intensity of 2.67. Water fetching is most intense at noon with a level of 3 and remains active until 6 PM. Relaxing peaks at 4 PM and 7 PM, both with intensities of 3.5.

Transport activities, mainly commuting, show clear peak times. The highest intensity for commuting is observed at 4 PM with a level of 3.875, remaining high until 7 PM. Morning peaks occur at 7 AM and 9 AM with intensities of 1.845 and 1.851 respectively.

These patterns show the dynamic use of streets in Mathare, with economic activities peaking in the morning and late afternoon, social activities taking a large part of the afternoon and evening and commuting showing distinct rush hour peaks in the morning and evening.

4.4 Adaptability per Road Design

4.4.1 Primary Roads:

Vending stands out as the most prominent and diverse economic activity on primary roads of Mathare. This activity was categorized into three types: vending from structures, on the road, and on carts. Vending from structures showed the highest frequency and intensity, with activity starting as early as 6:20 AM and continuing until very late evening. It peaks in the late afternoon and early evening, with the highest intensity of 4.3 which was observed at around 6:40 PM. This suggests that fixed vending locations are a crucial aspect of the local economy, mainly active during evening hours when residents may be coming back to their homes from work.

Other forms of vending show different patterns. Street vending and vending on carts have sporadic changes throughout the day, with intensities ranging from 1 to 4. These mobile vending activities appear to adapt to the changing rhythms of the street, catering to different customer needs at various times of the day that vary and require different supplies.

Garbage-related activities, including dumping, collection, and sorting, show a consistent presence throughout the day. This activity starts early, with an intensity of 2.8 at 6:40 AM, and continues intermittently until the evening, peaking at 3.5 at 12:50 PM. This implies that waste management is an ongoing economic activity on primary roads.

Motorbike stands represent another key economic activity. They appear in the early morning (3.5 intensity at 6:30 AM) and continue throughout the day, with changing intensities. This indicates the importance of motorcycle *bodabodas* in the local transport economy and the high intensity in the morning to transport people from one place to another.

Construction-related activities like carpentry, construction materials delivery, and metal fabrication/welding showed a limited time window. Carpentry, for instance, was recorded between 10:50 AM and 2:00 PM, suggesting it might be a daytime activity. Construction materials handling peaks at 10:00 AM with an intensity of 4, while metal fabrication appears sporadically during the day.

Firewood selling is another notable activity and starts from 9:40 AM to 5:40 PM. It shows relatively high intensities, with a peak of 4 at 2:30 PM and in the morning, indicating its importance in the local fuel economy. This time shows mainly the time when local vendors purchase firewood for preparing street food that peaks after the return of people from work. The morning hours also have high intensities because they are purchased by local brewers.

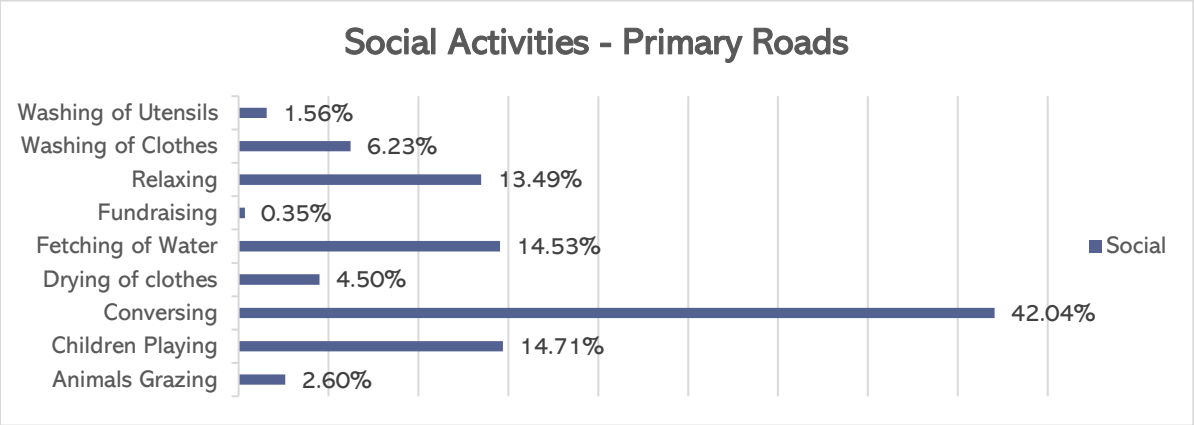
Scrap metal collection, though less frequent in the data, appears during morning and midday hours, suggesting it might be a supplementary economic activity for some residents.

Social Activities

Conversing emerges as the most frequent and widespread social activity on primary roads. It starts early in the morning, with an intensity of 2.50 at 6:10 AM, and continues throughout the day. The highest intensity for conversing is recorded at 4:00 PM with a level of 5, indicating

that late afternoon is a peak time for social interaction. This suggests that primary roads serve as important spaces for community engagement and information exchange.

Figure 5: Social Activities distribution along Primary Roads



Source : Mathare research Observation, 2024

Children playing is another significant activity, with entries scattered throughout the day. It starts as early as 9:40 AM with a high intensity of 5, and continues until early evening, with the last recorded entry at 6:10 PM. The varying intensities throughout the day suggest that children use the roads as play spaces when it's convenient or safe to do so.

Relaxing shows a pattern of increasing intensity as the day progresses. It starts with a low intensity of 1.50 at 6:40 AM, gradually increases, and reaches its peak at 2:30 PM with an intensity of 3.17. This indicates that people tend to use the roads more for relaxation in the afternoon hours.

Water-related activities, such as fetching water and washing clothes or utensils, showed an interesting pattern. Fetching water occurs throughout the day, starting early at 7:30 AM and continuing until 7:00 PM. This suggests that access to water is a constant need, with people using the roads to transport water at various times. Washing clothes and utensils appear less frequently but are spread across the day, indicating that these activities are performed when time and water availability allow.

Photograph 5:Washing and trading Activities

Source : Mathare research Observation, 2024

Drying of clothes is recorded from mid-morning to early afternoon, with intensities ranging from 1.00 to 2.50. This activity's timing corresponds to when household laundry is typically done and when sunlight is most available.

Photograph 6:Clothes Drying along the Road

Source : Mathare research Observation, 2024

Animals grazing and moving around, while less frequent, show high intensity when it occurs. The highest recorded intensity is 4.00 at 1:00 PM, suggesting that people use the roads to graze their animals, particularly during midday hours and this may be locals or non-locals of the settlement.

Fundraising appears only once in the data, at 2:10 PM with an intensity of 2.00. While not a frequent activity, its presence indicates that roads can also serve as spaces for community financial activities.

4.4.2 Collector Roads:

Economically, collector roads support smaller-scale vending activities and transportation services. Vending from structures is a prominent feature, with activity levels varying throughout the day. The intensity of vending from structures ranges from 1 to 3, with peaks observed in the afternoon and early evening hours. This suggests that these roads adapt to accommodate local businesses that serve the community's daily needs.

Motorbike stands are another significant economic activity on collector roads, with a recorded intensity of 3 at 9:20 AM. This indicates that collector roads play a crucial role in supporting local transportation services, and adapting to the community's mobility needs, particularly during morning hours.

Other economic activities observed on collector roads include metal fabrication/welding, scrap metal collection, and garbage dumping/collection/sorting. These activities, while less frequent, demonstrate the roads' adaptability to support various small-scale industries and essential services.

Socially, collector roads exhibit a high degree of adaptability, supporting a wide range of community interactions and activities. Conversing is a prominent social activity, with intensity levels reaching up to 4, particularly in the morning and afternoon hours. This suggests that collector roads serve as important spaces for community engagement and information exchange.

Photograph 7:Clothes Drying and People Conversisng along a Collector road

Source : Mathare research Observation, 2024

Collector roads also support essential daily activities such as fetching water, washing clothes, and drying clothes. These activities show varying intensities throughout the day, with peaks observed in the afternoon. This adaptability allows residents to use the road space for crucial household tasks, particularly when such facilities might be limited within individual homes.

Photograph 8:Fetching water and Washing clothes

Source : Mathare research Observation, 2024

Children playing is another significant social activity on these roads, with intensity levels ranging from 1.5 to 4. The presence of this activity throughout the day indicates that collector roads adapt to serve as informal play areas for local children, especially in the absence of designated playgrounds.

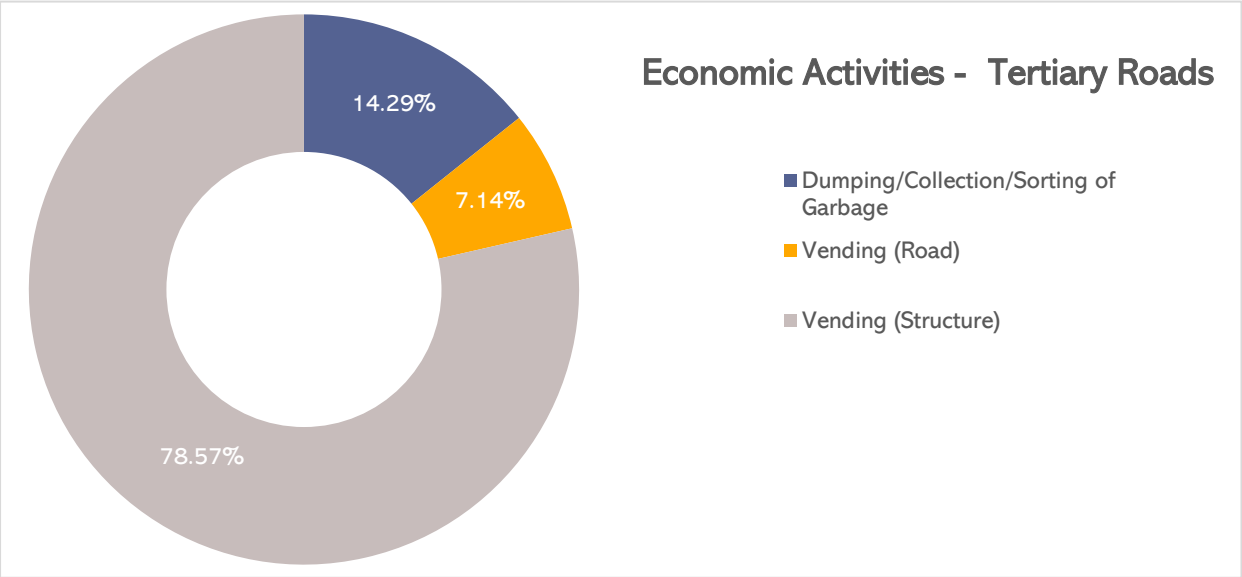
Relaxing is another social activity frequently observed on collector roads, with intensity levels reaching up to 3.5. This suggests that these roads adapt to serve as informal communal spaces where residents can unwind and socialize.

The presence of animals grazing further illustrates the multifunctional nature of these roads, adapting to support both urban and semi-rural activities within the informal settlement.

4.4.3 Tertiary Roads:

Economic Activities

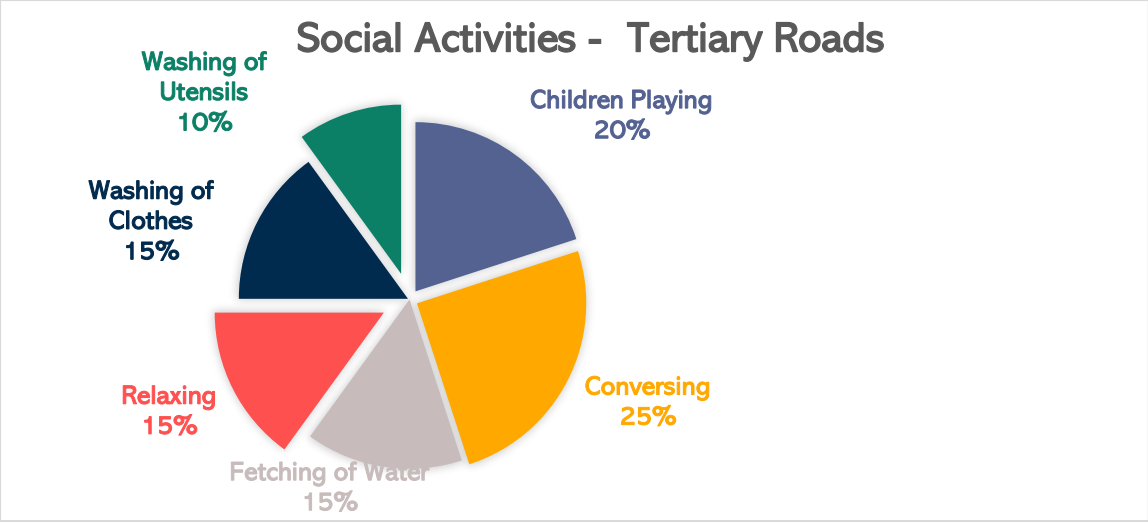
Figure 6: Economic Activities - Tertiary Roads



Source : Mathare research Observation, 2024

The versatility of economic activities in the tertiary streets is low evidenced by only having 3 economic activity typologies present within the observed Mathare tertiary streets which include Dumping and collection of garbage (, Vending by the road (7.14%) and vending on semi permanent structures within the street reserve

Figure 7: Social Activities - Tertiary Roads



Source : Mathare research Observation, 2024

The pie chart illustrates the social interactions and daily tasks that people engage in along tertiary roads in Mathare. The most common activity observed was conversing, which accounts

for 25% of the total. Following that, children playing accounted for 20%. Fetching water, washing clothes, and relaxing each makes up 15% of the activities. Lastly, washing utensils is the least common observed activity, at 10%. This chart highlights the tertiary roads.

4.5 Comparison of Adaptability per Road Design

4.5.1 Multifunctionality

Economic Multifunctionality

Primary roads in Mathare support the highest and most diverse range of economic activities. These roads are bustling with various forms of vending, including vending from structures, on carts, and on the road. Vending from structures is particularly prominent, with activities peaking in the late afternoon and early evening, such as at 6:40 PM with an intensity of 4.33. Other significant economic activities on primary roads include garbage collection, motorbike stands, and firewood selling, which show consistent presence throughout the day. The adaptability of primary roads is evident as they accommodate high-intensity activities at different times, making them crucial for the local economy.

Collector roads also support a variety of economic activities, though generally with lower intensity compared to primary roads. Activities such as metal fabrication, motorbike stands, and vending on the road are present, but with less frequency and intensity. For example, motorbike stands show an intensity of 3 at 9:20 AM, but this is less consistent throughout the day. Collector roads appear to be more specialized in certain activities, such as scrap metal collection and vending on the road, which occur at specific times but do not reach the same intensity levels as those on primary roads.

Tertiary roads support the least diverse range of economic activities. The data indicates that these roads are used for activities like vending on the road and from structures, but the intensity is generally lower. For instance, vending on the road peaks at an intensity of 2.5 at 7:30 AM, but this is not sustained throughout the day. Tertiary roads seem to cater to more localized and less frequent economic activities, reflecting their smaller size and possibly more residential nature.

Social Multifunctionality

All three road types show a high degree of social multifunctionality, supporting various activities such as conversing, children playing, relaxing, and essential tasks like fetching water and washing clothes. This suggests that regardless of road classification, these spaces serve as important social hubs for the community.

Primary roads appear to be the most versatile in accommodating social activities. They support the widest range of activities, including unique entries for animal grazing and fundraising, which are not recorded for the other road types. Primary roads also consistently show higher intensity levels for most activities, particularly for conversing and relaxing, with peak intensities reaching 5.0 and 3.17 respectively. This can be attributed to their width which allows them to manage to hold more activities compared to the other road types

Collector roads, while supporting many of the same activities as primary roads, generally show lower intensity levels. However, they appear to be particularly important for activities like washing clothes and drying clothes, with intensity levels sometimes exceeding those on primary roads.

Tertiary roads, based on the limited data provided, seem to support fewer types of social activities compared to primary and collector roads. The activities recorded for tertiary roads are primarily children playing, conversing, fetching water, relaxing, and washing clothes/utensils. This suggests that tertiary roads may have a more focused social function, perhaps due to their smaller size or location within the community.

In terms of temporal patterns, all road types show activity throughout the day, but primary roads appear to have more consistent and higher intensity use across different times. This suggests that primary roads may be more adaptable to changing social needs throughout the day.

4.5.2 Temporal Adaptability:

Primary roads exhibit the most diverse and intense activity patterns throughout the day. Economically, these roads show high activity levels from early morning to late evening. Vending activities, particularly from structures, peak in the late afternoon and early evening, with intensities reaching up to 4.33 at 18:40. Other economic activities like garbage collection and motorbike stands maintain a consistent presence throughout the day. Socially, primary roads are bustling with activity, especially in the afternoon. Conversing peaks at 16:00 with an intensity of 5, while children playing and relaxing show high intensities in the afternoon and early evening.

Collector roads demonstrate a more moderate rhythm of activities compared to primary roads. Economic activities on collector roads are less intense but still varied. Vending and motorbike stands show sporadic peaks throughout the day, with intensities generally lower than on primary roads. Social activities on collector roads follow a similar pattern to primary roads but with lower intensities. Conversing and relaxing activities peak in the afternoon, while water-related activities like washing clothes show higher intensities compared to other road types.

Tertiary roads show the least diverse and least intense activity patterns. Economic activities are limited, with vending being the primary activity recorded. The intensity of vending on tertiary roads is generally lower than on primary or collector roads, peaking in the morning and evening hours. Social activities on tertiary roads are also less intense, with children playing and conversing being the main activities recorded.

In terms of coping with high traffic and activity periods, primary roads appear to be the most adaptable. They maintain high levels of both economic and social activities throughout the day, suggesting they are designed to handle diverse and intense usage. The peak activity times on primary roads occur in the late afternoon and early evening, coinciding with the end of the workday and increased social interactions.

Collector roads experience their peak activities during mid-morning and afternoon hours. They appear to serve as intermediate spaces, balancing between the high-intensity activities of primary roads and the more localized use of tertiary roads. Their design allows for a mix of economic and social activities but at a lower intensity compared to primary roads.

Tertiary roads show less pronounced peak activity times, suggesting a more consistent, low intensity use throughout the day. Their design appears to cater more to local, residential needs rather than supporting high-intensity commercial or social activities.

The differences in daily activity patterns across these road types have implications for road use and urban planning. Primary roads, with their high adaptability and capacity to support diverse activities, serve as the main economic and social arteries of the community. Their design needs to accommodate this multifunctionality, potentially requiring wider spaces and more robust infrastructure.

Collector roads, balancing between high and low intensity uses, may require designs that allow for flexible use throughout the day, accommodating both through traffic and local activities. Tertiary roads, with their more localized and less intense use patterns, may benefit from designs that prioritize pedestrian safety and local access over high-capacity throughput.

4.5.3 Rhythms of Activities

Intermittent occurrences and intervals of social and economic interactions demonstrated by Mathare's streets highlight dynamic interaction in response to needs and opportunities at various times of the day.

Economic Activities

The data reveals daily fluctuations in economic activities, starting from early morning to evening. The day begins with a moderate level of economic engagement around 6 am with early business activities including vending and opening shops. This initial surge dwindles slightly but picks up again by mid-morning, reaching a peak in the afternoon, at around 4 pm. This pick may be as a result of more buying and selling activities that are being conducted by the residents as they make preparations for the evening. The distribution of daily economic activities remains high during late afternoon and early evening, gradually decreasing towards night.

Social Activities

Social activities follow a somewhat similar but distinct pattern. They start at an average level in the morning, reflecting interpersonal communication and morning routines. A notable peak occurs around 9 am, indicating increased social interactions likely due to school drop-offs, morning meetings, and group exercises. Another significant rise is observed in the late afternoon, peaking around 4 pm, corresponding to grocery shopping, sports, and interactions post-working hours. Social activities diminish towards evening, indicating that this is a period when people retire to their homes.

4.6 Perceptions of Residents on Street Design

From the interviews several challenges of planning for the group housing are evident. Silent growth results in an ability to state that the modern city is not properly aligned as a grid, unlike many other urban areas, which in turn has an impact on the application of conventional planning and organizing techniques. This creates the need for efficient methods of solving infrastructural challenges in a way that will not compromise the already limited living space. This was stated by one of the interviewees as, ***"The organic growth of the settlement makes it incredibly difficult to impose any structured street pattern without displacing residents"#2*** The issue here is to introduce those physical improvement changes that may lead to inconvenient displacement of the identified community. A similar sentiment was expressed by another interviewee ***"We have to balance the need for infrastructure with the limited space available, which is a constant challenge" #1*** One of the interview examples described the specified tension between implementing infrastructure development on one side and residents and their limited space on the other side. This is what a planning professional involved in informal settlement planning said, ***"Any planning intervention must consider the existing living conditions and avoid disrupting the community's daily life" #1***

Customized Planning Solutions

Each informal settlement is different in terms of the actors, their interactions, and the available space/land; thus, it requires a specific planning solution. Due to this, the standard planning principles have to be brought to practice in order to afford functionality as well as reverence to the communal conditions. One of the interviewees who expressed this said, ***"It is not biz as***

usual here; standard planning strategies do not apply here." The strategy that came out from the interviews stressed the formation of road networks which are hierarchal and functional and have due consideration to the context surrounding the specific settlement. Another participant said, ***"Our roads have to represent our encompassing community, how we go about our business as a community and not conform to the world's standards."*** This way developments made are relevant and can be sustained. The final interviewee contributed, saying, ***"The appropriate strategy is when there is the buy-in to meet the goals, it is sustainable because people are not just going to accept projects that are unpopular with their local leaders then abandon them."***

Community Involvement and Adaptability

The level of community engagement was identified as an important feature in planning in the informal settlement. There is no doubt that the involvement steps cannot be overlooked, mainly because they guarantee that the solutions proposed will be highly relevant, given that they have been informed by the needs and wants of the residents. Resident involvement in planning entails that the solutions set in place are sensible and embraced by residents The usage and modification of streets and public areas are greatly dependent on communities. One focus group discussion respondent stressed, ***'Our streets and spaces are not just pathways; they are a part of our lives, and they must be responsive taking into account our needs at specific times'***. For example, the development of specific strategies for the settlements such as Mathare, addressing the issue of upgrading the informal settlements is beneficial; however, it could have been more efficient if it consisted of a community approach.

4.7 Discussion

4.7.1 Relating Case Study to Existing Theory on Road Adaptability in Informal Settlements

Economic Adaptability

The observed peaks in economic activities mid-morning and late afternoon indicate that Mathare's residents are adept at timing their commerce to align with market demands. This flexibility is vital for the community's economic well-being, allowing them to adapt to the market's needs efficiently. This finding supports Lefebvre's (2013) rhythm analysis, which emphasizes the importance of cyclical time in urban spaces, showing how daily routines shape economic engagement. Additionally, the patterns observed align with Josephine et al., (2021), who noted that streets in informal settlements transform into productive spaces that actively contribute to the local economy. The adaptive use of streets for economic purposes also confirms the findings of Fauzi & Aditianata (2018), who emphasized the role of street vendors and informal economic activities in enhancing urban resilience.

Social Adaptability

The rhythms of social activities reveal a strong need for interpersonal interactions and communal support in Mathare. The high intensity of social networking during mid-morning and late afternoon highlights the community's emphasis on interpersonal relationships and group endeavours. This aligns with the findings of Mengistu & Jibat (2015), who highlighted the significance of streets as social arenas in informal settlements. The observed social adaptability also supports the work of The Hien Dang (2018), who discussed how informal vendors negotiate and interact with local citizens and authorities. Bringing up the importance of long-term relationships and social capital in facilitating interactions, streets in informal settlements facilitate these social interactions. Furthermore, the cyclical nature of these social activities is consistent with Procházková's (2018) application of rhythm analysis in understanding temporal dynamics in urban spaces.

Street Adaptability

The observed rhythms also highlight that Mathare's streets function as multifunctional infrastructure, accommodating both economic and social activities. The seamless blend of economic and social interactions throughout the day demonstrates the versatility of these streets. This flexibility is particularly crucial in informal settlements where space is limited, and maximizing the use of available areas is essential. This finding extends the work of Ulloa & Castillo (2020), who emphasized the multifunctionality of streets in urban settlements. Additionally, the adaptability of streets observed in Mathare confirms the theoretical insights of Fachrudin (2018) and Kotani et al. (2020), who highlighted the importance of street design in facilitating various urban functions.

4.7.2 Contributions to Theory on Road Planning in Informal Settlements

Adaptability and Multifunctionality

Mathare's streets exhibit significant adaptability and multifunctionality, serving as pathways for business and social interaction depending on the time of day. This ability to switch between these many functions is critical in the informal settlements where the limited space imposes urgent demands on the optimal utilization of available spaces. This research contributes to the theory by emphasizing the importance of flexible street designs that can transition between different uses, thereby enhancing community resilience (Marshall & Garrick, 2010). This finding are in alignment with Ehebrecht (2014), who discussed the need to to deviate from national norms and standards to enable alternative and innovative planning solutions. Moreover, it supports the work of Harsritanto (2018) and Siu & Wong (2015), who stressed the importance of multifunctionality and adaptability in urban planning.

Influence on Daily Rhythms

The physical form of the streets in Mathare informs when and where events occur, giving a rhythm the life of the settlement. In areas having more movement and exchanges, economic operations occur, while social interaction take place in safe and comfortable areas. This close relationship between the street character and behavior patterns guarantees harmonious coexistence in the settlement based on time and the space setting. This strong connection between street structure and activity patterns ensures the community's efficient functioning in space and time. This insight supports Lefebvre's (2013) rhythm analysis by demonstrating the practical implications of his theoretical framework. Furthermore, the observations align with the findings of Fauzi & Aditianata (2018) and Prelovskaya & Levashev (2017), who highlighted the spatial dynamics of street usage in informal settlements.

Road Planning and Upgrading

The observations of Mathare streets match with the tenets of road planning in informal settlements highlighted in the Integrated and Inclusive Infrastructure Framework for Kenya 3iF (2022). The observations and outcomes expand on several critical principles outlined in the framework emphasizing the multifunctionality of streets, highlighting them as vibrant economic and social hubs. This aligns with the 3iF's principle of planning and designing streets to support various functions, thus enhancing quality of life. Understanding the temporal dynamics of road usage using rhythms adopted contributes to the 3iF's emphasis on integrating multiple infrastructure systems and considering local knowledge. Inclusive infrastructure development is encouraged in 3iF by emphasizing community participation in road design and planning thus ensuring that what residents need and know is used to inform the planning process. These not only validate existing theories but also seek to enhance the practical framework for developing the adaptability and resilience of roads in informal settlements.

5 Chapter 5: Conclusions

5.1 Summary of Key Findings

This study on street adaptability in Mathare, an informal settlement in Nairobi, reveals distinct patterns of economic and social activities across different road types, demonstrating how street design influences adaptability to residents' evolving needs.

The research finds that primary roads exhibit the highest diversity and intensity of economic activities. Vending from structures is the most prominent, peaking in late afternoon and early evening with intensities up to 5 (on a scale of 1-5). Other significant activities include garbage collection, motorbike stands, and firewood selling, showing consistent presence throughout the day. Collector roads demonstrate moderate economic activity, with varied vending and waste management activities. Tertiary roads support lower-intensity economic activities, primarily local vending.

On Social Activities, primary roads are observed to be hubs for social interaction. Conversing peaks in the afternoon with an intensity of 5, while children playing and relaxing show high intensities throughout the day. Collector roads exhibit diverse social activities, including water-related tasks, with moderate intensities. Tertiary roads primarily support localized social interactions. Economic activities generally intensify from morning to late afternoon across all road types. Social activities peak in the afternoon and early evening, particularly on primary and collector roads.

The Spatial dynamics of primary roads reveal they function as major economic and social nodes, accommodating the highest diversity of activities. Collector roads serve as intermediate spaces, balancing various activities but with less intensity. Tertiary roads cater primarily to local, residential activities.

The study reveals that street design influences the type, intensity, and diversity of activities. Primary roads demonstrate the highest adaptability, supporting a wide range of functions throughout the day. Collector roads show moderate adaptability, while tertiary roads have more limited but essential local functions.

5.2 Answering the Research Questions

Main Research Question:

How does street design influence the adaptability of streets in Mathare to accommodate the evolving needs of the residents?

The study reveals that street design significantly impacts the adaptability of streets in Mathare, influencing the type, intensity, and diversity of activities they support. Primary roads, with their wider spaces and strategic locations, demonstrate the highest adaptability. They accommodate a broad range of high-intensity economic activities, such as vending from structures, which peaks at an intensity of 5 in the late afternoon. Social activities such as conversing and children playing also show high intensities, mainly in the afternoon, showing that primary roads serve as vital economic and social hubs.

Sub-Question 1

The rhythms of activities in Mathare streets change across the different road types and times of the day. Primary roads show a mixture of activities, with economic activities like vending reaching the peaks in the late afternoon and early evening. Social activities like conversing and children playing are very intense in the afternoon. Collector roads show moderate activity levels, comparing economic functions like vending and waste management with social

interactions. Tertiary roads, while less diverse, support essential local activities, primarily in the morning and afternoon.

Sub-Question 2

Street design has a crucial role in shaping the rhythms of activities. Primary roads, designed with wider sidewalks and more space, support high-intensity and diverse activities throughout the day. Their design allows for significant commercial activities, such as vending from structures, and social interactions. Collector roads, with moderate width and accessibility, support a balanced mix of activities but at lower intensities. Tertiary roads, being narrower and more localized, cater to low-intensity, essential activities, reflecting their design limitations in supporting diverse functions.

Sub-Question 3

Based on the findings, several design principles and policy recommendations can be formulated to create adaptable and inclusive streets in informal settlements. For primary roads, it is crucial to design wider sidewalks and flexible spaces that can accommodate high-intensity vending and social activities. These roads should also incorporate designated areas for essential services such as water points and waste management to support daily needs. Collector roads should be designed with moderate width to balance traffic and local activities while implementing spaces for small-scale economic activities and social interactions. Tertiary roads should prioritize pedestrian safety and local access, while still allowing for small-scale economic activities and essential services. Overall, these recommendations aim to enhance the multifunctionality of streets, catering to the diverse needs of residents in informal settlements while promoting safety, economic opportunities, and social cohesion.

5.3 Implications for Theory and Practice

Theoretical Implications

This study aims to expand Lefebvre's concept of rhythm analysis by applying it to the complex dynamics of informal settlements. The findings validate the importance of this framework in understanding the temporal and spatial patterns of street use in Mathare, contributing to the broader theoretical understanding of urban rhythms in informal contexts.

The research supports and expands upon the concept of streets as multifunctional spaces, as discussed by Marshall (2004). The observed patterns of economic and social activities across different road types (primary, collector, and tertiary) in Mathare demonstrate that streets in are not merely transportation corridors but vital public spaces supporting a wide range of community needs.

The study contributes to the theoretical framework of urban resilience by illustrating how street design influences adaptability to changing community needs. The varying intensities and types of activities observed on different road types provide empirical evidence for the concept of "spatial resilience" in urban systems, particularly in the context of Mathare.

The research enhances understanding of temporal rhythms in informal settlements, showing how daily, weekly, and seasonal cycles influence street use. This contributes to the theoretical discourse on time-space relationships in urban environments.

Practical Implications

Urban planners should consider a hierarchical approach to street design in informal settlements. Primary roads should be designed to accommodate high-intensity, diverse activities, while collector and tertiary roads cater to more localized needs.

Policymakers should implement flexible zoning regulations that allow for mixed-use development along primary and collector roads, supporting the natural multifunctionality of these spaces in informal settlements.

The observed temporal patterns suggest the need for time-based management strategies, such as allowing street vending during peak hours while ensuring clear pathways during commute times.

The complex interplay between street design and community activities underscores the importance of involving local residents in the planning process to ensure that street designs meet diverse needs.

The study highlights the need to integrate essential services (e.g., water points, waste management facilities) into street design, particularly along primary and collector roads, to support the multifunctional nature of these spaces.

5.4 Limitations and Future Research

There are limitations in the Mathare street adaptability study because it is an exploratory study. The data collection period coincided with demolitions, which might have affected residents' willingness to share information making the information unreliable. Additionally, the short three-week duration of the study did not provide enough time for a comprehensive understanding of street activities across seasons. Moreover, concentrating only on Mathare meant that findings could not be applied to other informal settlements with diverse characteristics. As an exploratory research design these limitations acknowledge the need for further work on these initial discoveries.

Future research should look at these limitations and elaborate on the results obtained from this research. Longer studies would allow better understanding of how seasons change street rhythms and to what extent external factors impact them. Expanding the research context to cover other informal settlements with varying characteristics would aid in generalizing results and show trends that are common across settings while revealing distinctive attributes of other places. Increased community participation, especially through employing local residents as research assistants or key informants would enhance data quality and also provide deeper insights into community experiences.

It is important to evaluate how certain interventions in urban planning affect street adaptability and the quality of life of residents. Use of advanced technological tools like GIS mapping, remote sensing and mobile data collection can be incorporated into the research in order to better the accuracy and coverage of spatial analysis in informal settlements. Therefore, this would lead to better understanding of street flexibility that will consequently inform improved urban designs as well as policies regarding these informal settlements.

5.5 Conclusion

This research provides recognition of the street design adaptability with a special emphasis on Mathare revealing how street-design is central to a variety of economic and social conducts in society. The study pays attention to the priority of comprehensible and community-led planning strategies and concerns the need for context-sensitive urban planning. These findings are beneficial to general theoretical knowledge on urban resilience and multipurpose space, and how intervention regarding housing needs a more specialized method essential for the informal settings.

Conditions that exist in this informal entail immediate improvement if the quality of life of millions of the population is to be improved. The authorities' adoption of the study's recommendations such as community planning, progressive upgrading regimes, as well as

infrastructure incorporation has the capacity to enhance the quality of existing areas. Thus, through improving street design, it is possible to make adaptations and provide the guidelines that will help enforce meaningful changes in the context of urbanization and make communities more productive and sustainable. Effort and commitment to study and enhance selected informal areas will foster essential and even revolutionary consequences for the enlargement of cities and welfare of their populations.

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Annex 1: Interview Guide: Interview with Chairperson – University of Nairobi

ERASMUS UNIVERSITY ROTTERDAM
INSTITUTE OF HOUSING AND URBAN DEVELOPMENT

I am ***Rex Otieno Omondi*** *a graduate student at Erasmus Universiteit Rotterdam pursuing a Masters degree in Urban Management and Development (Strategic Urban Planning and Policies).*

RESEARCH TITLE: Rhythm Analysis of Street Adaptability: Temporal and Spatial Dynamics in Informal Settlements for Enhanced Adaptability

RESEARCH PURPOSE: *The purpose of this study is to Identify and map the recurring patterns of activities that occur on Mathare's streets at different times and analyze how street design influences activity rhythms to Inform policy for promoting adaptable and resilient settlements through improved street functionality. The information and data collected will be confidential and are intended purely for the research study being undertaken for a project.*

INTERVIEW WITH CHAIRPERSON – UNIVERSITY OF NAIROBI – DEPARTMENT OF URBAN PLANNING

General Background and Expertise

1. Tell me about your background in urban planning and experience working with informal settlements, specifically Mathare.
2. What are the key challenges and opportunities for creating adaptable and inclusive streets in informal settlements?
3. In your experience, what role do streets play in the lives of residents in informal settlements like Mathare?

Street Design and Activity Rhythms

4. How does street design (width, sidewalks, greenery) influence the types of activities that occur there?
5. Provide examples of how specific design elements might encourage or discourage certain activities on a Mathare street.
6. Have you observed instances where street design changes impacted activity rhythms and functionality?
7. How can rhythm analysis help us understand the relationship between street design and activity patterns in informal settlements?

Adaptable and Inclusive Street Design

8. What design principles can create streets that adapt to the changing needs of Mathare residents?
9. How can we incorporate multifunctionality into street design to cater to diverse activities throughout the day?
10. What are key considerations for creating safe and inclusive street spaces for all users (children, vendors, pedestrians)?

Policy Considerations for Adaptable Streets

11. What are some key policy considerations for encouraging adaptable and inclusive street spaces in informal settlements?
12. In upgrading programs, how can policy ensure street improvements don't disrupt activity rhythms or displace residents?
13. What specific policy recommendations would you suggest for developing adaptable and inclusive streets in informal settlements?

14. What are the biggest policy barriers to implementing adaptable street design solutions in Mathare?
15. Beyond design principles, are there crucial policy interventions for creating adaptable streets?
16. How can existing land-use policies be adapted to better support adaptable and inclusive streets?
17. How can research on street rhythms and adaptability inform more effective policies for informal settlement planning?

Looking Forward

18. What are the biggest challenges in implementing adaptable street design solutions in Mathare?
19. Are there any innovative projects or case studies showcasing adaptable street design in informal settlements?
20. What role do you see for community participation in designing and managing streets in informal settlements?
21. How can research on street rhythms and adaptability inform future urban planning practices for informal settlements?
22. Do you have any additional insights or recommendations regarding street design and adaptability in Mathare?

Annex 2: Focus Group Discussion Guide:

ERASMUS UNIVERSITY ROTTERDAM
INSTITUTE OF HOUSING AND URBAN DEVELOPMENT

*I am **Rex Otieno Omondi** a graduate student at Erasmus Universiteit Rotterdam pursuing a Masters degree in Urban Management and Development (Strategic Urban Planning and Policies).*

RESEARCH TITLE: Rhythm Analysis of Street Adaptability: Temporal and Spatial Dynamics in Informal Settlements for Enhanced Street Adaptability

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FOCUS GROUP DISCUSSION GUIDE

Identify and map the recurring patterns of activities that occur on Mathare's streets at different times.

1. Can you describe the various activities that take place on the streets of Mathare at different times of the day? *Unaweza kunielezea shughuli hufanyia katika street ya Mathare wakati tofauti wa siku kwa the streets?*

2. Do these activities change based on the time of day, days of the week, or seasons of the year? Please provide examples.

Je, shughuli hizi hubadilika kulingana na saa za siku, siku za wiki au majira ya mwaka? Toa mifano.

3. Are there any activities that occur at specific times or during special occasions? What makes those activities unique?

Kuna shughuli yoyote inayofanyika time specific au katika matukio maalum? Kitu gani kinafanya shughuli hizo kuwa different hivo?

4. Do you notice any changes in street activities based on seasonal changes or other events? Please elaborate.

Unaona changes zozote katika shughuli za street kulingana na mabadiliko ya time au matukio mengine? Eleza zaidi.

5. What makes certain areas of the streets more active than others?

Ni nini hufanya baadhi ya sehemu za street/barabara kuwa na shughuli nyingi kuliko sehemu zingine?

Analyze how street design influences activity rhythms.

1. Do you think the design of the streets (such as width, presence of sidewalks, and greenery) affects the activities that take place there? Why?

Unadhani muundo wa roadi/street (kama vile size/upana na kuwa na places za kutembelea) unaathiri shughuli zinazoendelea hapo? Kwa nini?

2. Are there specific street design features that make it easier or harder for you to carry out certain activities? Please provide examples.

Kuna vigezo vya muundo wa streets vinavyokufanya upate ugumu au urahisi wa kufanya shughuli fulani? Toa mifano.

3. Have you ever witnessed any changes in street activities due to modifications in street design or layout?

Umeshawahi ona changez zozote kwa shughuli za street kutokana na mabadiliko ya muundo au mpangilio wa hiyo street?

4. What Street design features do you think can facilitate multiple activities happening simultaneously?

Ni vigezo gani vya muundo wa Barabara/street unaona zinaweza kurahisisha shughuli mbalimbali kufanyika kwa wakati mmoja?

5. Are there any areas of the streets that you think should be modified to allow more activities to take place there? Why?

Kuna maeneo yoyote ya babarara/street ambayo unadhani inafaa kubadilishwa ili kuruhusu shughuli zaidi kufanyika hapo? Kwa nini?

Inform policy recommendations for promoting adaptable and resilient settlements through improved street functionality.

1. Based on your experience living here, what design principles should guide the creation of adaptable streets that can accommodate the changing needs of residents?

Kulingana na uzoefu wako kuishi huku, ni kanuni gani za muundo wa street zinazofaa kutumika ili kujenga street inayoweza kubadilika na kukidhi mahitaji ya wakazi?

2. Are there any policy recommendations you can suggest to ensure the vitality and functionality of the streets are maintained even after upgrading programs?

Kuna mapendekezo yoyote ya sera ungependekeza ili kuhakikisha street inabaki na uhai na utendaji wake hata baada ya mipango ya uboreshaji?

3. What street design modifications would you recommend to improve the ability of the streets to accommodate the evolving needs of residents?

Ni mabadiliko gani ya muundo wa street ungependekeza ili kuboresha uwezo wa street kukidhi mahitaji ya wakazi yanayobadilika?

4. What are some ways in which the government and other stakeholders could involve the community in street improvement plans?

Kuna njia gani serikali na washika dau wengine wangeweza kuhusisha jamii katika mipango ya kuboresha street?

5. What challenges do you face in trying to adapt the use of street spaces to accommodate your needs?

Ni changamoto gani unazipata katika kujaribu kubadilisha matumizi ya maeneo ya street ili kukidhi mahitaji yako?

Rhythm Analysis of Street Adaptability

LOCATION *

Annex 3: Observation Matrix

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

STREET PAVING *

- ◯ Tarmac
- ◯ Cabro
- ◯ No Pavement (Earth)

TIME *

yyyy-mm-dd hh:mm

STREET

- ◯ Mau Mau Road
- ◯ White Castle street
- ◯ No 10 Street
- ◯ Road Next to St James

ACTIVITY INTENSITY

Vending activity intensity can range from [Low: 1-2 vendors] to [Medium: 3-6 vendors], and even to [High: more than 6 vendors]. Commuting or pedestrian movement intensity is measured by the number of people passing by in a short period, with [Low: 1-5 pedestrians in 2 minutes], [Medium: 11-20 pedestrians in 2 minutes], and [High: more than 20 pedestrians in 2 minutes]. Socializing or social gathering intensity is gauged by the number of distinct groups, from [Low: 1 small group] to [Medium: 2-5 groups], and [High: more than 5 groups]. Finally, children's playing intensity is assessed by counting children in the area, with [Low: 1-3 children], [Medium: 4-10 children], and [High: more than 10 children].

WHAT IT THE CURRENT FLOODING SITUATION ON THE STREET?

Describe the drainage conditions and whether there is presence of stagnant water along the street as a result of the heavy rains

CURRENT STATE PHOTOGRAPH *

Click here to upload file. (< 10MB)

ACTIVITY	PRESENCE	INTENSITY	SPATIAL DISTRIBUTION	ADDITIONAL OBSERVATIONS
RELIGIOUS GATHERING S/CRUSADES	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

RELIEF DISTRIBUTION	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
STREET PERFORMANCES	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

CONSTRUCTION OR REPAIRS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
COMMUNITY MEETINGS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

WASTE COLLECTION	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
CHILDREN PLAYING	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

CELEBRATIONS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
COMMUTERS AND TRANSPORTATION	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

CLEANING	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
RECYCLING/ SCRAP METAL COLLECTION	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

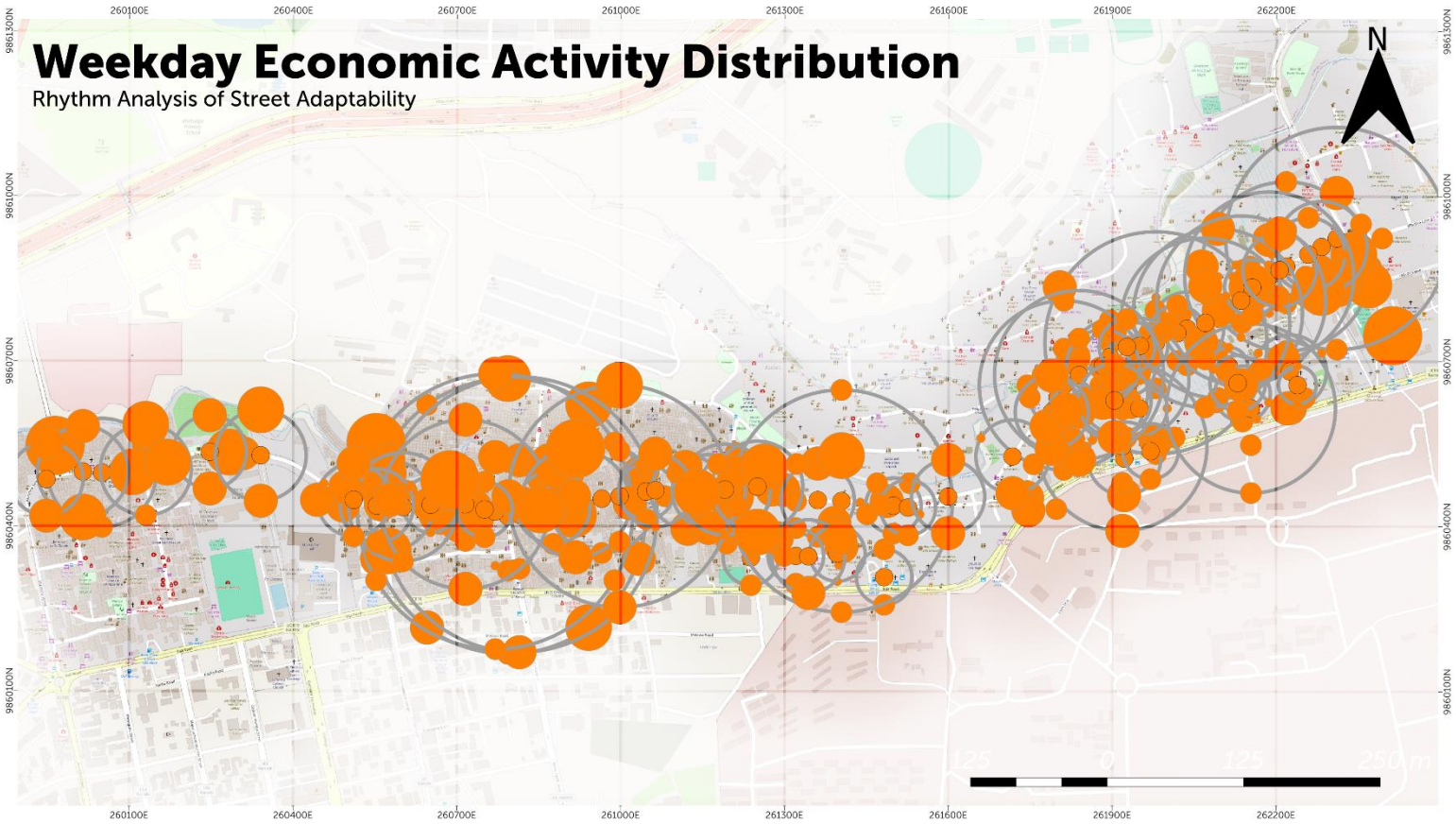
RESTING	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
FUNERAL GATHERING	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

HEALTHCARE SERVICES: MOBILE CLINICS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
VENDING - SELLING OF GOODS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

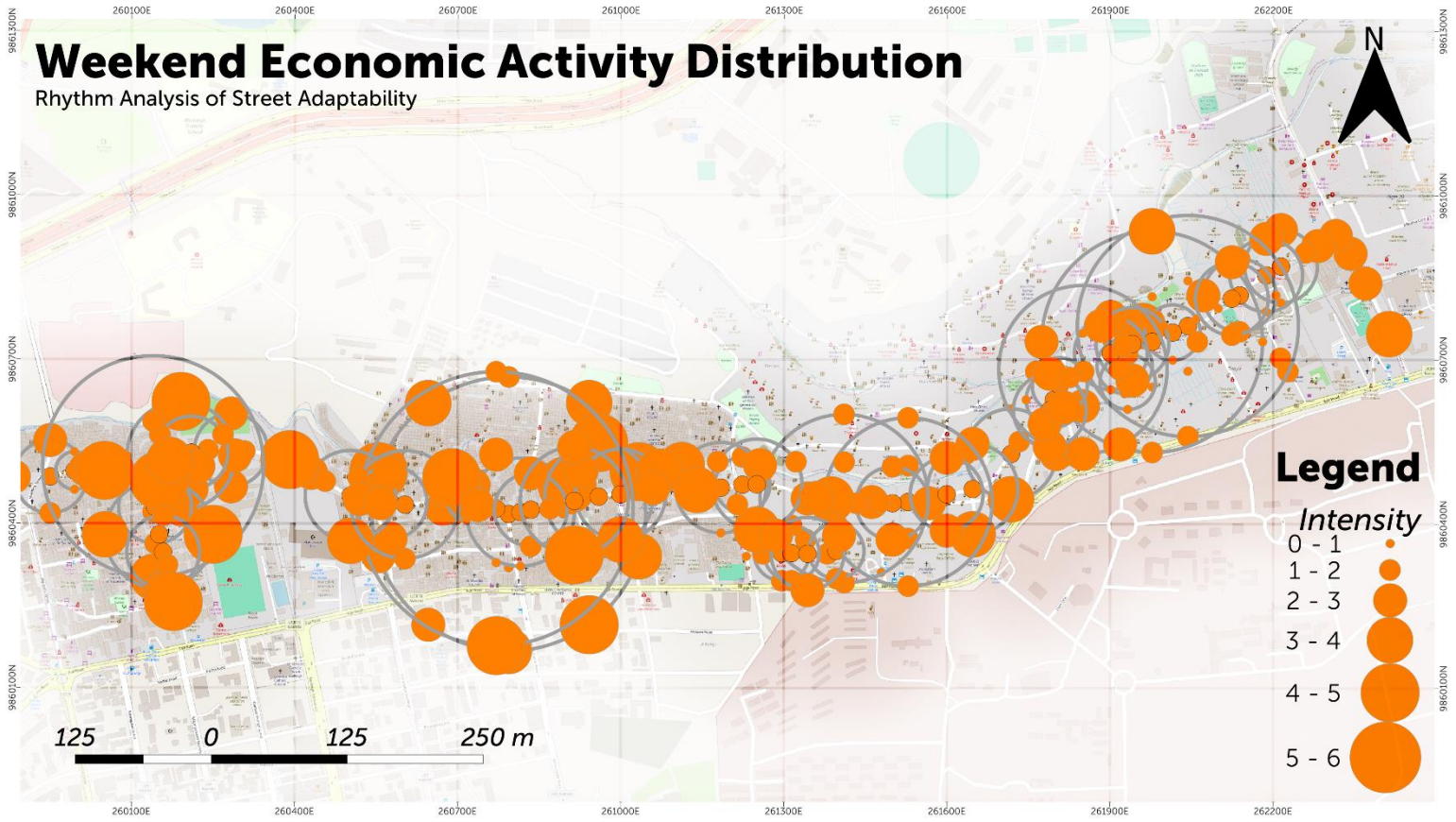
PARKING/ WAITING SPOT IE FOR BODA BODA & CARS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	
SOCIAL GATHERINGS	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	

WATER DISTRIBUTION/FETCHING	◯ Yes ◯ No	◯ High ◯ Medium ◯ Low ◯ Not Applicable (N/A)	◯ Linear along street ◯ Concentrated at one point ◯ Scattered ◯ Clustered ◯ Not Applicable (N/A)	.....

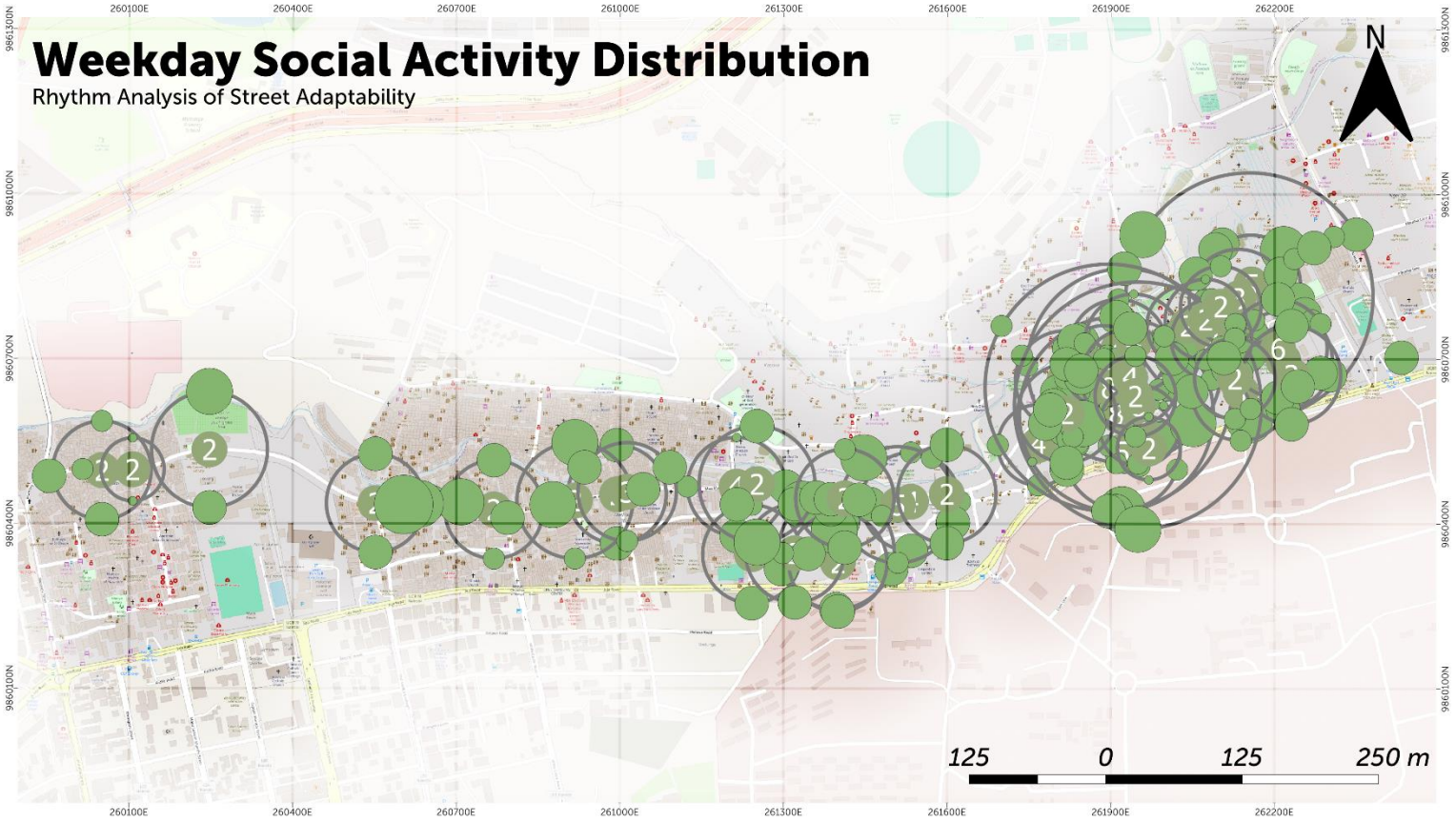
Map 3: Weekday Economic Activity Distribution



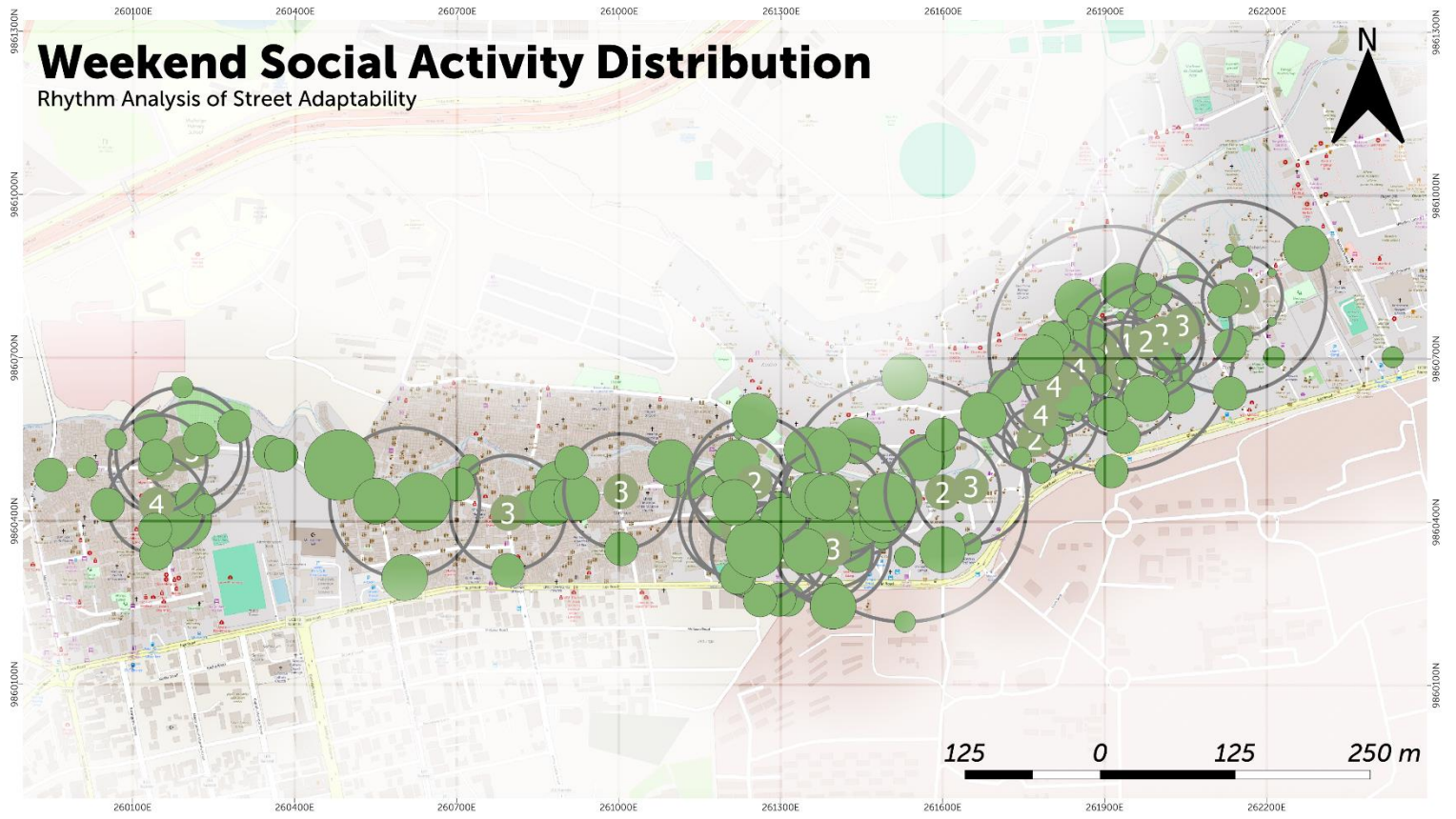
Map 4:Weekend Economic Activity Distribution



Map 5:Weekday Social Activity Distribution



Map 6:Weekend Social Activity Distribution



Annex 4: Python Code to generate random observation times

```
import random

# Define the start and end times

start_time = 6  # 6:00 AM

end_time = 22   # 10:00 PM

# Generate random observation times for each hour

for hour in range(start_time, end_time+1):

    for minute in [0, 15, 30, 45]:

        random_minute = random.randint(minute, minute+14)

        observation_time = f"{hour:02d}:{random_minute:02d}"

        print(observation_time)
```

Sample

06:08 06:22 06:41 06:54 07:03 07:19 07:32 07:46

Annex 5: Research Timeline

S/NO	Main Agenda	Specific Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	Proposal Development	Preliminary Research (Research Design)	■	■	■	■					
		Refining of Research Topic questions and methodology	■	■	■	■	■	■	■		
		Draft Proposal	■	■	■	■	■	■	■		
		Student atelier meeting with Kenyan Partners to pitch draft proposal *(18th March 2024)*			■						
		Final proposal and Submission				■	■	■	■	■	
2	Thesis Development and Data Collection	Literature review and secondary data collection				■	■	■	■	■	
		Preparation of primary data collection tools				■	■	■	■	■	
		Primary data collection					■	■	■	■	
		Presentation of data collection outcome to Nairobi partners									■
		Primary data collection days: *(11th May 2024, 17th May 2024, 18th May 2024, 21st May 2024)*					■	■	■		
		Key activities: Mathare site visit *(7th May 2024)*, UN Civil Society Conference *(9th May 2024)*					■				
		Transect walk *(11th May 2024)*, Debrief meeting *(20th May 2024)*					■				
		Presentation of preliminary research findings and analysis *(10th June 2024)*						■			
		Interview with Chairperson UoN - DURP *(24th June 2024)*, Interview with Geodev Kenya Urban Planner *(27th June 2024)*						■			
3	Data Analysis	Data compilation							■	■	
		Secondary and Primary data analysis							■	■	
		Thesis report preparation							■	■	
4	Thesis Report	Submission of the first draft							■		
		Finalization of thesis proposal								■	
		Submission of the final draft								■	
		Presentation of the final draft to partners								■	
		Submission of final research *(2nd August 2024)*								x	

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