**MORPHOLOGY OF STREET NETWORKS IN URBAN NEIGHBORHOODS IN GHANA – chapter one**

**Introduction**

Street networks form the vessels through which the lifeblood of human settlements (people, services, goods, and information) flow. They underlie commutes, discretionary trips, and the location decisions of households and firms (Boeing, 2018a). More importantly, they help shape the urban structure and shape the way human interactions happen in space. They are so important and prevalent in our lives that it would be impossible to imagine a world in which street networks do not play an important role in how we live and interact with the immediate environment and the people around us.

The current output of urban transportation efforts in Ghana is subpar—and mostly becomes more of a problem after commissioning—, this can be experienced by any person living in any city in Ghana. Commute times are longer because it takes twice as much time to travel between two endpoints. There is a huge divide between academic output on the subject and actual implementation of these ideas in our cities mostly due to the informal ways in which they evolve—that is if they are even considered at all—, as (Dumedah & Garsonu, 2021) posits, “very little is known from the literature about the spatial structure of urban road networks in Ghana, sub-Saharan Africa, or in areas with the similar informal layout of roads”. It will get increasingly harder to do Urban Planning in Ghana specifically in the transport sector because without a comprehensive view of the network structure and the possible effects of particular changes in intricate parts of the structure, planning efforts will continue to be shots in the dark and create more problems than they intend to solve.

Establishing a clear relationship between street networks and their impact on the functioning of urban systems is necessary to better the planning of these systems. The spatial structure of street networks is essential to their function and performance, especially in the way they facilitate the flow of information (people, goods, services) between interconnected parts of the urban systems as a whole. Walkable and drivable street networks, an essential part of street networks can be investigated further using the computational network science approach, to tease out different variables that characterize them, from their configuration and structure to answering questions about the resilience of these networks, how they evolve and affect the way interaction happens in space.

Understanding the composition, configuration, and decisions underlying the way urban neighborhoods and cities are shaped helps shape future planning decisions and provides an avenue to scrutinize and better evaluate the effects of urban transportation planning efforts in Ghanaian cities and their neighborhoods. Accordingly, this study uses the computational network science approach as described by Geoff Boeing in his 2017 paper introducing OSMnx—a new tool to make the collection and analysis of urban street network data simple, consistent, and reproducible (Boeing, 2017)—to tease out the variables that characterize the network structure and form of neighborhoods across two cities in Ghana, Accra, and Kumasi.

Consequently, using the computational network science and data science approach, this study provides a comprehensive description of street network topology and geometry across neighborhoods in two cities, in Ghana. The study examines the structural configuration of street networks in these neighborhoods, limiting the scope to data from Accra and Kumasi. This is because they possess fine-grained road networks comparable to cities on a global scale based on intersections and street densities (Dumedah & Garsonu, 2021). The study of the structural configurations and topology provides insight into the strengths of weaknesses of the network, and the structural arrangements that make networks resilient. Resilient networks improve accessibility for all people, reduce commute times, and have a positive impact on the proper functioning of other parts of the urban system. Whereas a street network system that is poorly designed without any insights into its structure and configuration, negatively impacts society as a whole.

**Background**

Street networks in their primal form are systems of interconnected lines and points (edges and nodes in network science) which represents the street and road networks in any given area. The nodes (points) represent the intersection of roads and dead-ends whilst the edges represent the road segments connecting these points (Barthélemy, 2011; Boeing, 2017, 2020b).   
The forms that arise from the intricate interconnections of the nodes and edges making up the street networks are soo crucial they determine how we live and work in our cities; they affect lifestyle choices by influencing how mobile we can be; they influence health choices by affecting whether we choose to walk, bike or drive to destinations; and in cases of natural disasters, how fast disaster response can reach victims in need of help (Zamanifar & Hartmann, 2021).

Rapid urbanization and its associated effects on street networks and urban form have been widely studied and reported in Ghana (Cobbinah et al., 2016; Yankson, Paul, and Bertrand, 2012), this, coupled with the ad hoc approach to transportation planning that usually involves the expansion of street networks in cities to accommodate the increasing traffic with limited consideration for spatial configurations the network (Dumedah & Garsonu, 2021) the problems are becoming harder to ignore. Accordingly, these problems result in a significant impact on the performance of streets and street networks, and other urban systems that rely on street networks to function appropriately.

Even though there exists not much literature studying urban street networks in Ghana, many studies have been emerging all over the world studying topological relations, connectedness, and resilience of street networks (Boeing, 2018a, 2018b; Zhao et al., 2019), using empirical methods that are open and reproducible and can be taken advantage of by urban planners, researchers, and pedagogy to better understand street networks and how they affect and shape human interactions and settlement decisions.

The lack of reproducible and open methods for street network analysis in Ghana makes it harder to understand how transportation and all urban planning, in general, is carried out. There exist few empirical studies on urban networks making it harder to break into the field, especially for interested undergraduate students. Adopting a computational science approach to analyzing and understanding urban networks coupled with open data and tools gives students at all levels the opportunity to take advantage and to study and produce research that seeks to understand urban street network form.

Against this background, the main goal of this study is to fill in the gap in research works that seek to understand the structure of existing street networks in Ghana, specifically Accra and Kumasi by studying the structure of random neighborhoods from each of the selected sites. To that end, this study seeks out how, using the graph-theoretic approach and tools, network configuration variables such as centrality, connectedness, and connectivity along with design-oriented variables like width, length, circuity, and street layout can play important roles in enabling a more conducive city that makes life and interaction easier.

**Research Questions**

1. Which source can be used to get replicable and accurate data on street networks in Ghana?
2. Which relevant tools can be used to accumulate data, model, and visualize data to be able to tease out the metrics that help understand urban street networks.
3. How relevant are the measured metrics to understanding the form and structure of street networks in urban neighborhoods?
4. How can we effectively and sustainably operationalize the open and reproducible computational science approach to studying urban street networks and incorporate it into transportation planning and urban planning to achieve desired results?

**Research Objectives**

1. This research aims to seek out reproducible and open ways for securing and analyzing street network data.
2. The research aims to take a modern computational data science approach by the use of portable computational notebooks to create replicable and verifiable analyses and comparisons of street network structure and form across city neighborhoods in Ghana.
3. The study aims to employ a graph theoretic approach to analyzing street networks using the OSMnx and NetworkX (Boeing, 2017, 2019).
4. This study aims to assess the relevance of the approach to be used in this research in pedagogy, research and practice.

**Material and Methods**

**study area and data sources**

The study area comprises [number] of neighborhoods randomly selected from two of the most developed and populated cities in Ghana, namely Accra, and Kumasi. The density, topological and geometric differences across these neighborhoods are contrasted with each other and occasionally with others on a global scale. Though not entirely the focus of this study, the selected study areas have fine-grained networks—a relatively well-interconnected street network system (Dumedah & Garsonu, 2021)—as can be seen in [figure number]. It also is the case that, Accra and Kumasi are the most mapped out cities in Ghana, on the OpenStreetMap index for Ghana, they rank high in average entries and possess more data points than any other city in Ghana. This is relevant as it gives us more variables to investigate and make inferences from.

The street network data for the study is obtained from OpenStreetMap, an open and collaborative mapping project that provides free and open spatial data for almost all places in the world. Spatial data provided is fine-grained and numerous, ranging from building footprints, walkways, bikeways, roads, overpasses, bridges, railroads, and land use, and even in the more developed countries, it contains navigation data. In countries like Ghana, where there is a lack of well-developed Geospatial Science and Technology agencies that can provide spatial data like the above for practitioners and pedagogy, OSM (OpenStreetMap) is incredibly valuable and its importance cannot be overstated. Since OSM at its core is an open-source project, any individual is allowed without much verification to contribute to its vast spatial database. This is not much of a problem since data from OSM has been used in major research works in urban informatics over the years (Boeing, 2017, 2020a, 2021; Dumedah & Garsonu, 2021; Sharifi, 2019).

**tools and analysis framework**

There are several ways of acquiring data from the OSM database, the old way is by the use of the API (Application Programming Interface), Overpass, which can be queried to retrieve data from the database and is the default tool provided by the OSM project. Over the years, many people have tried to make it easier for practitioners and pedagogy to retrieve data from the database without much hassle and one of such tools which has caught on well is one developed by a Professor of Urban Informatics at the University of Southern California, Geoff Boeing. The tool, OSMnx (OpenStreetMap and NetworkX) (Boeing, 2017) presented in the 2017 eponymous paper, is a python programming language library that makes it easy to retrieve and analyze the street network data of any place in the world. OSMnx analyzes street networks by converting street network data points obtained from OSM into mathematical graphs, specifically multigraphs (Boeing, 2017). The tool has been featured in many studies of street networks since its conception, notable is a study of road networks in Ghana by (Dumedah & Garsonu, 2021).

Other tools used in this study include; QGIS, the Python programming language, and the Jupyter Lab computation notebook for downloading, aggregating, analyzing, and visualizing open and freely available spatial data. One of the aims of this study is to construct a study using open tools and data that can be replicated, to that end, all data and automation scripts used in the study can be found at [github.com/Joe-Degs/AutoGIS](https://github.com/Joe-Degs/AutoGIS/tree/master/test-thesis)

**Significance of Study**

The world is changing rapidly and technology has opened up new avenues for people in research, and pedagogy to understand our environments and the Spatio-temporal interactions that shape them. Using these new approaches in urban informatics it is possible to simulate future changes before rolling them out into physical space for human interaction. Street networks form the substrate for all human dynamics in space and understanding their structure and effects on spatial interactions will lead to making better decisions in urban planning efforts.

The importance of research seeking to understand street network form and morphology cannot be overstated in public health where researchers are showing the strong correlation between health and walkability and bike-ability of neighborhoods (Marshall et al., 2014), and in disaster management where understanding street network structure and form is helping plan better incident response (Zamanifar & Hartmann, 2021). It is most important that we study street networks because, they are amongst the most long-lived components of urban form and can stay in place for decades, sometimes even centuries. Therefore, their design and structure are likely to lock urban systems in either their positive or negative pathways (Sharifi, 2019)

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