**Morphology of street networks in urban neighborhoods in Ghana**

A Special Study submitted to the Department of Planning, Kwame

Nkrumah University of Science and Technology, Kumasi

in partial fulfilment of the requirements for the

Degree of Bachelor of Science in Human Settlement Planning

By

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**September, 2022**

**CHAPTER ONE**

**GENERAL INTRODUCTION**

**1.1 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 - sthis 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 (2021a) argue, “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 (Dumedah & Garsonu, 2021b; Masoumi et al., 2019).

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 (Boeing, 2019; Sharifi, 2019). 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 (Boeing, 2018a; Sharifi, 2019).

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, 2017a)—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 neighborhoods in 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, 2021a). 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 (Sharifi, 2019; Sharifi & Yamagata, 2018).

Therefore, this research seeks to use an computational open-science approach to study street networks by converting street networks into primal graphs from which topological and geometric metrics can be gathered and analysed (Boeing, 2017b). It also contributes to the current tool landscape in the pedagogy and policy by creating and documenting a minimal framework for the study of street networks. All tools and data used in the study are free and open to the general public, making all the work carried out in this study easy to replicate and reproduce.

**1.2 Problem Statement**

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, 2017a, 2020).   
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 (Sharifi, 2019; 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, 2021a) 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 (Sharifi, 2019).

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 (Dumedah & Garsonu, 2021a). 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 randomly selected neighborhoods from each city. 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.

**1.3 Research Questions**

The research seeks to provide answers to the following questions:

1. Which sources and tools help in securing replicable and accurate data on street networks in Ghana?
2. Which relevant tools and methods 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 is the computational network science approach to understanding the form and structure of street networks in urban neighborhoods?
4. How can cities 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?

**1.4 Research Objectives**

The main aims of the research is:

1. To identify reproducible and open ways for securing and analyzing street network data.
2. To explore modern computational data science approaches and freely available spatial data and tools to create replicable and verifiable analyses and comparisons of street network structure and form across city neighborhoods in Ghana.
3. To assess the importance of using open-data, open-science with the benefits of network science in the study of street networks on the local scale.
4. To provide a comprehensive addition to the current toolset and resources needed for effective studying of street networks and provide a minimal framework that can built upon to increase scope of studies like this done in Ghana.

**1.5 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).

**1.6 Organisation of Study**

This document is presented as follows; chapter one includes an introduction and background of the study, stating the relevant problems and questions that the research seeks to address and its significance to the current research landscape. Chapter two contains a literature review of street networks and street network analysis using the methods and tools sought after by the author of this research, it surveys the current literature and discusses their influence on this study. It reviews and asserts the importance of doing open research and engaging in research tool building and and how these efforts help contribute to the current research landscape. Chapter three presents the analytical framework, tools, resources and methodologies used to conduct the study. It continues to make the case for freely available and open tools and how relevant they are to conducting verifiable and good research, not forgetting study areas and data sources relevant to the study. This chapter also serves as a brief documentation of relevant tools used in conducting the study. Chaper four presents the findings of the research, discusses the relevance of the findings to the current literature and objectives of the study. It presents the answers to the research questions and relates them to how they affect real world variables and scenarios. Finally, chapter five presents a summary of the entire researh, presenting the major arguments, findings and discussions from the study. It concludes by stating areas of further research and contribution.

**References**

Barthélemy, M. (2011). Spatial networks. *Physics Reports*, *499*(1–3), 1–101. https://doi.org/10.1016/J.PHYSREP.2010.11.002

Boeing, G. (2017a). OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks. *Computers, Environment and Urban Systems*, *65*, 126–139. https://doi.org/10.1016/j.compenvurbsys.2017.05.004

Boeing, G. (2017b). OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks. *Computers, Environment and Urban Systems*, *65*, 126–139. https://doi.org/10.1016/J.COMPENVURBSYS.2017.05.004

Boeing, G. (2018a). The Morphology and Circuity of Walkable and Drivable Street Networks. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3119939

Boeing, G. (2018b). Urban Spatial Order: Street Network Orientation, Configuration, and Entropy. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3224723

Boeing, G. (2019). Urban spatial order: street network orientation, configuration, and entropy. *Applied Network Science*, *4*(1). https://doi.org/10.1007/s41109-019-0189-1

Boeing, G. (2020). Planarity and street network representation in urban form analysis. *Environment and Planning B: Urban Analytics and City Science*, *47*(5). https://doi.org/10.1177/2399808318802941

Cobbinah, P. B., Poku-Boansi, M., & Asomani-Boateng, R. (2016). Urbanisation of Hope or Despair? Urban Planning Dilemma in Ghana. *Urban Forum*, *27*(4). https://doi.org/10.1007/s12132-016-9293-9

Dumedah, G., & Garsonu, E. K. (2021a). Characterising the structural pattern of urban road networks in Ghana using geometric and topological measures. *Geo: Geography and Environment*, *8*(1). https://doi.org/10.1002/geo2.95

Dumedah, G., & Garsonu, E. K. (2021b). Characterising the structural pattern of urban road networks in Ghana using geometric and topological measures. *Geo: Geography and Environment*, *8*(1), e00095. https://doi.org/10.1002/GEO2.95

Marshall, W. E., Piatkowski, D. P., & Garrick, N. W. (2014). Community design, street networks, and public health. *Journal of Transport & Health*, *1*(4), 326–340. https://doi.org/10.1016/J.JTH.2014.06.002

Masoumi, H. E., Terzi, F., & Serag, Y. M. (2019). Neighborhood-scale urban form typologies of large metropolitan areas: Observations on Istanbul, Cairo, and Tehran. *Cities*, *85*, 170–186. https://doi.org/10.1016/j.cities.2018.09.005

Sharifi, A. (2019). Resilient urban forms: A review of literature on streets and street networks. *Building and Environment*, *147*, 171–187. https://doi.org/10.1016/J.BUILDENV.2018.09.040

Sharifi, A., & Yamagata, Y. (2018). Resilience-Oriented Urban Planning. *Lecture Notes in Energy*, *65*, 3–27. https://doi.org/10.1007/978-3-319-75798-8\_1

Yankson, Paul and Bertrand, M. (2012). *Introduction : challenges of urbanization in Ghana*. https://www.researchgate.net/publication/280638627\_Introduction\_challenges\_of\_urbanization\_in\_Ghana

Zamanifar, M., & Hartmann, T. (2021). Decision attributes for disaster recovery planning of transportation networks; A case study. *Transportation Research Part D: Transport and Environment*, *93*, 102771. https://doi.org/10.1016/J.TRD.2021.102771

Zhao, P., Yen, Y., Bailey, E., & Sohail, M. T. (2019). Analysis of urban drivable and walkable street networks of the ASEAN smart cities network. *ISPRS International Journal of Geo-Information*, *8*(10). https://doi.org/10.3390/ijgi8100459