Analyzing Spatial Distribution Patterns of Visual Indicators of Slum Conditions: Case of Rajarghat, Kolkata, India

Bryan Tramontina

Follow this and additional works at: https://knowledge.library.iup.edu/etd

Part of the Geography Commons

Recommended Citation
https://knowledge.library.iup.edu/etd/1471

This Thesis is brought to you for free and open access by Knowledge Repository @ IUP. It has been accepted for inclusion in Theses and Dissertations (All) by an authorized administrator of Knowledge Repository @ IUP. For more information, please contact cclouser@iup.edu, sara.parme@iup.edu.
ANALYZING SPATIAL DISTRIBUTION PATTERNS
OF VISUAL INDICATORS OF SLUM CONDITIONS:
CASE OF RAJARGHAT, KOLKATA, INDIA

A Thesis
Submitted to the School of Graduate Studies and Research
in Partial Fulfillment of the
Requirements for the Degree
Master of Science

Bryan Tramontina
Indiana University of Pennsylvania
May 2017
Indiana University of Pennsylvania
School of Graduate Studies and Research
Department of Geography and Regional Planning

We hereby approve the thesis of

Bryan Tramontina

Candidate for the degree of Master of Science

Sudeshna Ghosh, Ph.D.
Assistant Professor of Geography and Regional Planning, Chair

Brian Okey, Ph.D.
Associate Professor of Geography and Regional Planning

Richard Hoch, Ph.D.
Associate Professor of Geography and Regional Planning

Randy L. Martin, Ph.D.
Dean
School of Graduate Studies and Research
Title: Analyzing Spatial Distribution Patterns of Visual Indicators of Slum Conditions: Case of Rajarghat, Kolkata, India

Author: Bryan Tramontina

Thesis Chair: Dr. Sudeshna Ghosh

Thesis Committee Members: Dr. Brian Okey
Dr. Richard Hoch

With the continuing rise of urban and slum populations, new ways of studying the slum phenomenon and slum conditions are of growing importance. This study analyzes the spatial distribution patterns of visual indicators of slum conditions in Rajarghat, a slum settlement in Kolkata, India. Using field observation and GPS survey data, the visual indicators developed in this study are: 1) Housing Condition, 2) Access to Water, 3) Access to Sanitation, and 4) Access to Amenities. I then apply spatial analysis techniques, such as Local Moran’s I and HotSpot Analysis to assess these patterns. Significant patterns, both clustering and dispersion, were found. An index of adequacy is also created to further assess the slum conditions of Rajarghat. Repeatable methods are also generated for future, similar analysis.
ACKNOWLEDGEMENTS

I would first and foremost like to thank my thesis committee members Dr. Sudeshna Ghosh, Dr. Brian Okey, and Dr. Richard Hoch for all their help and encouragement. I would also like to extend an even more special thanks to my thesis chair, Dr. Sudeshna Ghosh. Without her guidance through both the thesis writing process and the streets of Kolkata, this would not have been possible.

I would also like to thank all the other students and professors from Indiana University of Pennsylvania (IUP) and Indian Institute of Technology (IIT) who helped collect data during our field study trip to India: Dana Keith, Dylan Murphy, Guadalupe Ortiz-Cortez, Hortencia Correa, Rachel Wasilko, Carl Wells, Dr. Haimanti Banerji, Dr. Subrata Chattopadhyay, Nihal Singh Verma, Samya Rakshit, Shantanu Gupta, and Subhas Bera.

Finally, I would like to thank my girlfriend Cassie for putting up with me this past year, and my parents John and Marilyn and my sister Adrienne for putting up with me for much longer than that.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONE INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Research Questions</td>
<td>3</td>
</tr>
<tr>
<td>Research Objectives</td>
<td>4</td>
</tr>
<tr>
<td>TWO LITERATURE REVIEW</td>
<td>5</td>
</tr>
<tr>
<td>Theories of Slum Formation and Slum Growth</td>
<td>6</td>
</tr>
<tr>
<td>Policies for Slum Redevelopment and Upgrading</td>
<td>10</td>
</tr>
<tr>
<td>Social Capital in Slum Settlements</td>
<td>16</td>
</tr>
<tr>
<td>Infrastructure and Slum Measurement/Assessment</td>
<td>19</td>
</tr>
<tr>
<td>Spatial Analysis in Slums</td>
<td>25</td>
</tr>
<tr>
<td>Literature Review Conclusion</td>
<td>28</td>
</tr>
<tr>
<td>THREE DATA AND METHODS</td>
<td>31</td>
</tr>
<tr>
<td>Case Study of Rajarghat</td>
<td>31</td>
</tr>
<tr>
<td>Development of Slum Condition Indicators</td>
<td>35</td>
</tr>
<tr>
<td>Housing Conditions</td>
<td>36</td>
</tr>
<tr>
<td>Access to Water</td>
<td>38</td>
</tr>
<tr>
<td>Access to Sanitation</td>
<td>38</td>
</tr>
<tr>
<td>Access to Amenities</td>
<td>38</td>
</tr>
<tr>
<td>Data Collection</td>
<td>40</td>
</tr>
<tr>
<td>Spatial Analysis</td>
<td>45</td>
</tr>
<tr>
<td>Development of Index of Adequacy</td>
<td>48</td>
</tr>
<tr>
<td>FOUR RESULTS AND DISCUSSION</td>
<td>51</td>
</tr>
<tr>
<td>The Slum Conditions in Rajarghat</td>
<td>51</td>
</tr>
<tr>
<td>Spatial Patterns of Slum Condition Indicators</td>
<td>60</td>
</tr>
<tr>
<td>Index of Adequacy Assessment</td>
<td>64</td>
</tr>
<tr>
<td>FIVE CONCLUSION</td>
<td>73</td>
</tr>
<tr>
<td>Scope of Future Research</td>
<td>79</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>80</td>
</tr>
<tr>
<td>Table</td>
<td>Title</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>1</td>
<td>Housing Structure Examples</td>
</tr>
<tr>
<td>2</td>
<td>Housing Structure Breakdown</td>
</tr>
<tr>
<td>3</td>
<td>Moran's I Results</td>
</tr>
<tr>
<td>4</td>
<td>Index of Adequacy</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Needs vs amenities pyramid</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Selected Literature</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Location of Rajarghat in relation to Kolkata/Hooghly River</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>Map of Rajarghat showing canal, main road, and vacant land</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>Attempts at slum upgrading in Rajarghat, photo credit Nihal Verma</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>Methodology flowchart</td>
<td>35</td>
</tr>
<tr>
<td>7</td>
<td>Housing adequacy metric</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>A fully non-permanent house</td>
<td>39</td>
</tr>
<tr>
<td>9</td>
<td>A water tap</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>A toilet structure over the canal</td>
<td>39</td>
</tr>
<tr>
<td>11</td>
<td>A cement sanitation facility</td>
<td>39</td>
</tr>
<tr>
<td>12</td>
<td>A house with a satellite dish</td>
<td>39</td>
</tr>
<tr>
<td>13</td>
<td>A locking sanitation facility</td>
<td>39</td>
</tr>
<tr>
<td>14</td>
<td>Area of slum sampled</td>
<td>43</td>
</tr>
<tr>
<td>15</td>
<td>All housing points</td>
<td>44</td>
</tr>
<tr>
<td>16</td>
<td>Locations of water taps and sanitation facilities</td>
<td>44</td>
</tr>
<tr>
<td>17</td>
<td>A model used to streamline the buffer/dissolve/clip process</td>
<td>47</td>
</tr>
<tr>
<td>18</td>
<td>Kernel density maps</td>
<td>49</td>
</tr>
<tr>
<td>19</td>
<td>Houses sorted by building material</td>
<td>52</td>
</tr>
<tr>
<td>20</td>
<td>Fully permanent houses</td>
<td>53</td>
</tr>
<tr>
<td>21</td>
<td>Land use map 2011. Source (Sen 2011)</td>
<td>53</td>
</tr>
<tr>
<td>22</td>
<td>All water taps and sanitation facilities</td>
<td>55</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>23</td>
<td>100 foot water tap buffer</td>
<td>57</td>
</tr>
<tr>
<td>24</td>
<td>50 foot water tap buffer</td>
<td>57</td>
</tr>
<tr>
<td>25</td>
<td>200 foot water tap buffer</td>
<td>58</td>
</tr>
<tr>
<td>26</td>
<td>100 foot sanitation facility buffer</td>
<td>58</td>
</tr>
<tr>
<td>27</td>
<td>50 foot sanitation facility buffer</td>
<td>59</td>
</tr>
<tr>
<td>28</td>
<td>200 foot sanitation facility buffer</td>
<td>59</td>
</tr>
<tr>
<td>29</td>
<td>All structures with satellite dishes</td>
<td>61</td>
</tr>
<tr>
<td>30</td>
<td>Structures with locking or private toilets</td>
<td>61</td>
</tr>
<tr>
<td>31</td>
<td>HotSpots of non-permanent houses</td>
<td>63</td>
</tr>
<tr>
<td>32</td>
<td>Clustering of non-permanent houses</td>
<td>63</td>
</tr>
<tr>
<td>33</td>
<td>HotSpots of structures with satellite dishes</td>
<td>65</td>
</tr>
<tr>
<td>34</td>
<td>Clustering of structures with satellite dishes</td>
<td>65</td>
</tr>
<tr>
<td>35</td>
<td>HotSpots of locking or private toilets</td>
<td>66</td>
</tr>
<tr>
<td>36</td>
<td>Clustering of locking or private toilets</td>
<td>66</td>
</tr>
<tr>
<td>37</td>
<td>Permanent housing kernel density map</td>
<td>68</td>
</tr>
<tr>
<td>38</td>
<td>Access to water kernel density map</td>
<td>68</td>
</tr>
<tr>
<td>39</td>
<td>Access to sanitation kernel density map</td>
<td>69</td>
</tr>
<tr>
<td>40</td>
<td>Access to amenities kernel density map</td>
<td>70</td>
</tr>
<tr>
<td>41</td>
<td>All four kernel density maps combined</td>
<td>71</td>
</tr>
<tr>
<td>42</td>
<td>Combined kernel density map (survey area only)</td>
<td>71</td>
</tr>
<tr>
<td>43</td>
<td>Non-permanent home with a satellite dish and a home housing rag picking</td>
<td>74</td>
</tr>
</tbody>
</table>
CHAPTER ONE
INTRODUCTION

The growth and spread of slums has become a global phenomenon and a global challenge of increasing concern throughout the last century, particularly for the cities of the developing world. Large urban centers across the world from Asia, to Africa, to the Americas continue to see exponential population growth. Projections show that, by 2050, continued urbanization and population growth will add approximately 2.5 billion people to the world’s total urban population (UN World Urbanization Prospects, 2014). This rapid population growth contributes to an exponential growth of slums as well. Growing cities are often not prepared to cater to the basic needs of new urban citizens due to an inadequate supply of low-income housing and basic infrastructure. As a result, millions of people squat in slums, the urban fringes and marginal lands within cities, often without access to durable housing, water, sanitation and amenities. To be considered a slum, according to the United Nations definition, an area must meet one or more of the following conditions: lack of durable or protective housing; lack of access to safe, sufficient, affordable water; sharing of bathroom facilities among large groups of people; residential overcrowding, and insecure land tenure/lack of ownership (United Nations Human Settlements Programme, 2003).

The United Nations Human Settlement Programme estimated in 2003 that about 32% of the world’s urban population, or approximately one billion people were living in slum conditions (United Nations Human Settlements Programme, 2003). By the year 2030 the total world population is projected to reach 8.5 billion (UN Projects World Population to Reach 8.5 Billion by 2030, 2015) and the total worldwide slum population is projected to reach 2 billion (Eaves, 2007).
As in other developing world countries, India is experiencing rapid urbanization and the migration of millions of people from rural to urban areas. Indian cities are expected to witness continued rapid growth of slum populations in the coming years and decades. By the year 2030 India’s overall population is expected to reach 1.5 billion (Akkoc, 2015). If the percentage of the total Indian population living in slums (5.3%) remains the same over that time, that will mean an estimated 80 million people will be living in slums by the year 2030 (Census of India, 2011). That is likely a very conservative estimate, however, as other projections show that by as early as 2017 there will be an estimated slum population across India of over 100 million people, around 9% of the total population (Dash, 2013). India’s ability to deal with the challenges associated with this population and slum growth will be at the forefront of the nation’s continued path of modernization. As Roy (2009, p. 77) states: “India’s urban growth is so dramatic that it ‘consistently outstrips even the most perspicacious planner’s vision for it’”. Planning in India is often an effort in futility. For example, the new Bangalore airport was built 21 miles outside the city. Roads were insufficient for the amount of traffic generated, and water supply had not reached the airport area (Roy, 2009). How can a nation that struggles to plan be able to - or expected to - plan for a massive influx of new citizens and the slums that grow as a result?

Kolkata, a rapidly growing “Global City” in eastern India with a metropolitan region population of 14 million as of 2011, has witnessed a sharp increase in its slum population since the 1970s (Census of India, 2011). For decades, Kolkata has maintained its regional role as a center for capital and labor and this leads to continued increases in rural to urban migration, with Kolkata as the urban destination. This leads to a rise in urban population, and in turn, a rise in the slum population (Sengupta, 2007). Recent estimates place the number of slum dwellers in Kolkata at around 1.4 million, or about one-third of the city’s urban population (Census of India,
These increases in population will continue in the coming years, and only with more research and better planning will negative side effects be alleviated.

The purpose of my research is to understand the housing conditions and adequacy of infrastructure in the slums of Kolkata. I apply a case study approach to assess a specific slum settlement, Rajarghat, located in the eastern fringe of the Kolkata metropolitan area. Issues of deficient and insufficient infrastructure, as well as poor living conditions, are common in slums across Kolkata. I chose Rajarghat for its unique economic and geographic characteristics. While Rajarghat has many similarities with a typical slum, its proximity to a large landfill site and wetland area offers a potentially unique economic and geographic niche for the community.

The broader goals of my research are to understand existing slum conditions by measuring and analyzing indicators of housing conditions and infrastructure deficiency. My research spatially analyzes the indicators of 1) Housing Condition, 2) Access to Water, 3) Access to Sanitation, and 4) Access to Amenities within the slum and visualizes that data in a way that supports further research, and urban planning initiatives. I utilized both the Global Positioning System (GPS) and visual observations as well as applied spatial analysis techniques such as Moran’s I and Getis-Ord G analysis in my research.

**Research Questions**

The key questions posed in my research are:

- What are the slum conditions in Rajarghat?
- Do the visual indicators of slum conditions exhibit any spatial pattern?
- How can the slum conditions be assessed based on an index of adequacy?
  
  “Adequacy” in this research is defined as possessing sufficient access to water, sanitation, amenities and permanent housing.
Research Objectives

The specific objectives of my research are:

1) To conduct a GPS and visual observation survey to develop four indicators of slum conditions:
   i. Housing Conditions
   ii. Access to Water
   iii. Access to Sanitation
   iv. Access to Amenities

2) To analyze this data using Geographic Information Systems (GIS) to characterize spatial distributions and patterns.

3) To create an index of adequacy to describe slum conditions in a way that can be compared to other slums.

The approach used to achieve these objectives included travelling to Rajarghat to gather primary data on visual indicators of slum conditions with the use of GPS, photograph and written accounts; inputting/transferring this data to a computer and to ArcGIS; mapping and analyzing this data with the use of spatial autocorrelation, Local Moran’s I, and Getis-Ord G analysis; determining the importance and extent of any patterns that are found; and creating maps to display the locations of the visual indicators, as well as the patterns that are evident.
CHAPTER TWO
LITERATURE REVIEW

There is an extensive amount of literature covering slums. Certain aspects of the phenomenon are researched and written about more comprehensively than others for reasons such as funding availability and the potential benefits that certain types of research may provide in real-life situations. My literature review focuses on five key ideas: (a) slum formation and slum growth, (b) policies for slum redevelopment and upgrading, (c) social capital in slum settlements, (d) infrastructure and slum measurement/assessment, and (e) spatial analysis in slums. I break down each of these four areas and examine prominent and relevant schools of thought within each. As I began my research, my focus was primarily on wide ranging slum-related issues such as living conditions and infrastructure. I found literature which looked at how slums are deemed to be slums in the first place and then on how they are measured. This led to research about specific infrastructure, quality of life and health related concerns than can arise within a slum. It also led to some of the important literature regarding slums in South America and the writings of Janice Perlman.

With a base of knowledge regarding what a slum is and an understanding of life within a slum, my research then led me to examine why exactly slums exist and grow in the first place. Concepts regarding rural to urban migration, overabundance of unskilled labor, and the informal sector were at the forefront in this portion of the literature as well as the role that slums can play in a rapidly growing and urbanizing city. From there my research led to what types of policies and actions are being implemented in the effort to positively impact the conditions of slums and the lives of those who live there. My research showed the evolution of ideas regarding slum improvement from early ideas of slum demolition to more modern ideas of bottom-up and self-
help methods of upgrading. I found the writings of key researchers like Robert Werlin and John Turner to be particularly important and influential in that regard. This combination of literature and knowledge led to the realization that often, slum dwellers are comfortable in their current condition, or at least do not want to leave their current environs. The logical question to that is why? This led to my research and review of literature regarding social capital. The writings of Robert Putnam were of particular importance here. He writes about the inherent value of social capital and networking and the positive effects those can have on physical and human capital, as well as of the sense of community that social capital can and does foster. Finally, I sought out literature that was tangential to my own research. For this, I examined research and literature that examined spatial analysis and its relation to slums and slum conditions.

**Theories of Slum Formation and Slum Growth**

When examining the slum phenomenon, one can begin with the reasons why slums come into existence. The concepts of migration, slum formation, and slum growth are important to geographers, and have been studied at length to understand why people move where they do, which places grow at faster rates than others and why.

The growth of slums is at least partly attributable to an influx of new residents to urban areas. This occurs as a result of migration, and often mass migration; the question then is: why do people migrate? The answer is more complex than simply attempting to better one’s life. Lee’s (1966) theory of migration lists four factors which play into a person’s decision to migrate:

1. Factors associated with the area of origin.
2. Factors associated with the area of destination.
3. Intervening obstacles.
4. Personal factors
This can be summed up as, is the destination location more favorable than the current location? What is standing in the way? And do any specific personal things make migration more or less advantageous (Lee, 1966)? Lee’s writings on the theory of migration are influenced by the much earlier writings of Ravenstein (1889) in his seminal work “The Laws of Migration.” In it he concludes that migrants will generally travel a relatively short distance towards a center of commerce and industry which will then “absorb” the migrants. This in turn will lead to people from further and further away migrating to areas abandoned by previous migrants in waves that will spread outward from the major city centers. He also states that migration increases where there is more manufacturing and more technology to aid in migration. Most importantly he finds that while other factors like climate, oppression and taxation do play a role in migration, the most compelling reason is in fact “the desire inherent in most men to 'better' themselves in material respect” (Ravenstein, 1889, p. 286).

As Lee (1966) states “The volume of migration varies with fluctuations in the economy… Unless severe checks are imposed, both volume and rate of migration tend to increase with time” (Lee, 1966, p. 53). From 1800 to 2000 the percent of the world’s population living in an urban environment has risen from 3% to 47%. By 2030, due mainly to urbanization occurring in the developing world, this percentage is likely to reach 60% (Bolay, 2006). As cities and urban areas grow at a high rate, they are often not ready or able to deal with the influx of new residents. In the five South Asian metropolises of Karachi, Mumbai, Delhi, Kolkata and Dhaka there are an estimated 15,000 slum communities with a total population of 20 million. Many of these slums have been described almost callously as dumping grounds of “surplus humanity,” human warehouses for migrants with nowhere else to go (Davis, 2003). The aforementioned city of Dhaka, the Capital of Bangladesh is a prime example of rapid urban
growth and its role in the slum phenomenon. As Hossain (2008) put it, “The city of Dhaka follows the pattern of urbanization without development, the opposite of the expectations and aspirations of the poor there.” (p. 1). Dhaka has experienced a large migration from rural Bangladesh, as well as a large rise in poverty. Infrastructure is insufficient to keep up with this migration, leaving large portions of the populations to resort to living in slums and informal settlements. Thus, these slum dwellers have limited access to the formal aspects of the city (Hossain, 2008). This limited access to the central aspects of urban areas was also observed by the seminal researcher, John Turner, who observed that many slum dwellers (termed “squatters”) are forced to the periphery of the city, effectively cut off from, and unable to work in, the city center (Turner, 1968). The phenomenon of urban growth outpacing development is a key aspect in the growth of slum communities in many urban areas. Although increased urban population in developing countries generally leads to growth of slums and slum populations, the effect that that population growth has on economic growth is questionable. Furthermore, economic growth that is expected to flow downward to slum dwellers rarely materializes (Fox, 2014).

Other ideas regarding slum development and theory focus on the growth of the city, the influx of population and the varying skills and assets of that incoming populace. As Stokes (1962) states, “Assuming that slums do have a function in the development of the city...this function evolves...and has a direct relation to the growth of the city” (p. 187). As he postulates, “the slum is the home of the poor and the stranger” with the poor not able to fully integrate for economic reasons, and the stranger due to their culture not allowing them to fully integrate (p.

---

1 In Bangladesh specifically, in 1901 only around 2% of the population lived in urban areas. However, after steady increases over the course of the century, over 23% of the population were living in urban areas by 2001. While the population of the country as a whole grew 5 times larger, the urban population grew about 7 times larger. By 2001, the population of Dhaka alone made up nearly 1/12th of the national population and over 1/3 of the nation’s urban population. From 1991 to 2001, the population of Dhaka rose from under 7 million to over 10.7 million, a large increase which has put intense pressure on city infrastructure and caused many people to live in slums and informal settlements. By 1996 approximately 1.1 million people in Dhaka were living in slums (Hossain, 2008).
188). Strangers come to the city seeking to improve their lives, yet they are often prevented from doing so by language or education barriers. This is often true in areas where waves of migrants exceed the number of available jobs. When the incoming migrant population enters a city that cannot fully “absorb” them, those with more ability are more likely to be readily absorbed than those without labor-ready abilities (Stokes, 1962). If unskilled laborers attempt to enter a workforce which cannot absorb them, they are far more likely to make less money and resort to living in slum areas, increasing the population thereof.

Though slum dwellers are not wealthy or employed in skilled jobs, they still make up a large portion of the workforce as part of the informal sector. The informal sector is made up of the surplus of workers who do not fit into the formal labor sector (Banerjee, 2004). Types of jobs performed by the informal sector can include housekeeping, driving, or informal subsistence practices such as fishing or even farming. One important occupation of many slum dwellers, which is intriguing on multiple levels, is rickshaw pulling. Rickshaws are an important source of income within the informal sector despite the fact that their use was technically made illegal. By providing alternate forms of transportation, rickshaw pullers not only make money to benefit the drivers and their families themselves and the informal economy as a whole, but also provide a valuable service to the community (Hyrapiet and Greiner, 2012). The role played by the informal sector is important for society and the economy, and contributes toward urban sustainability. Rickshaws, for example, provide income for the poor and a pollutionless form of transportation (Whitelegg and Williams, 2000). Without the services provided by members of the informal sector, the formal sector would likely suffer. Policies in years past were sometimes focused on removing slums altogether. These methods, however, do not account for the potential of slum dwellers to alleviate, on their own, some of the problems they are said to face. Nor do they
account for the benefits that slums provide for a city. As Bolay (2006, p. 284) states, “In the contemporary era of globalization, it is important to stress the resources that slums can offer the ‘chaotic’ city”. This helps to explain why slums exist, why they continue to grow, what roles they play in an urban environment and why they function as they do.

**Policies for Slum Redevelopment and Upgrading**

The next important set of ideas and practices regarding slums is that of slum redevelopment and upgrading. Because people and governments are trying to change, enhance, improve or even eliminate slum conditions, this area of research is of immense importance to planners. There is a vast array of literature on ideas regarding slum policy; theories that have failed, theories that show potential, and theories that have yet to be fully implemented. This is an area which has drawn significant amounts of funding due to the potential of providing real world solutions, and therefore sees an abundance of research and literature on the topic.

While much research has shown that slums are not necessarily a “problem” per se, efforts are still underway to try to improve slum environments and the lives of people who live there. Slum reform, redevelopment and upgrading in India are ever-evolving subjects of inquiry. Andavarapu and Edelman (2013) describe four distinct phases in the evolution of slum redevelopment; the first phase of these strategies was to demolish slums and replace them with public housing. This was seen to have a doubly negative effect, both by disrupting the culture of the neighborhoods, and by placing more financial stress on the residents. The second phase of strategies was considered slightly more effective and beneficial, and involved viewing slums as “less the problem than the solution”. This phase granted tenure security to female heads of household and saw in slums the ability to self-upgrade over time. Furthermore, it sought to give slum dwellers more ability to help themselves. Some of this self-upgrading involved providing access to infrastructure like proper toilets and safe water sources. Unfortunately, much of these
improvements were only superficial at best and did not tackle real issues of livelihood and sustainability. The third phase of strategies is referred to as “enablement”. This strategy involves joint effort by government and private investors to eliminate or improve slum conditions. In many cases, the strategy resulted in immense bureaucratic red tape and ambiguous guidelines which slowed any real progress. The final and current strategy known as “National Slum Upgrading” calls for governments to form comprehensive policies to reduce poverty and increase sustainability. Unfortunately, this strategy tends to result in poor quality government-funded projects, built by third-party contractors, with little input from the public. Andavarapu and Edelman (2013) conclude that public-private partnerships, when incorporating public input, and improve quality of life would help the urban poor. These four phases of ideas can be seen and examined as one looks at different attempts, and methods of slum redevelopment.

Research has been done to look at the cycles of urban poverty in India and what can be done by authorities to help stop the cycle. Despite some progressive policies, there is often little to no regard for the poor, and in some cases, settlements have even been demolished (Pal, 2006). Chaudhuri (2013), created a resource called the “sustainable livelihood framework” and eventually determined that not enough is being done by authorities to stop this cycle of poverty. When a government does step in with an effort to promote housing reform, it often only benefits the upper and middle classes and not the poor living in the slums (Chaudhuri, 2013). Despite housing reforms, formal housing has yet to offset the growth of slums. Informal housing is growing at double the rate of planned housing. Kolkata itself has seen no increase in low income group’s access to housing, and housing reforms appear to have benefitted all but the low-income groups (Sengupta, 2007).
In the 1970s The Kolkata Metropolitan Development Authority with the assistance of the World Bank set out to improve slum infrastructure (water, sewage, pavement) without altering the slum houses themselves. This type of improvement was accepted and welcomed by slum dwellers. Other attempts at modernization were less successful. Proposals were put forth to rehouse residents of Chetla in South Kolkata in four story apartments, however the residents refused to move there. Similarly, new homes were built in Salt Lake for slum-dwelling fishermen who had been evicted, but they too refused to move there. In the North Kolkata slum of Rambagan, however, slum dwellers teamed up and worked with the Ram Krishna Mission charitable organization and donor agencies to fund and build several four-story apartments that were occupied and used by the slum dwellers (Ghosh and Ghosh, 2011). Efforts to upgrade slum conditions and infrastructure have thus produced mixed results; one view regarding why so many government led efforts fail and why more success can be found in efforts that integrate input from slum dwellers can be summarized in John Turner’s 1st Law from his book ‘Freedom to Build’: “When dwellers control the major decisions and are free to make their own contribution to the design, construction or management of their housing, both the processes and the environment produced stimulate individual and social well-being. When people have no control over nor responsibility for, key decisions in the housing process, on the other hand, dwelling environments may instead become a barrier to personal fulfillment and a burden on the economy.” (Turner and Fichter, 1972, p. 241). In other words, success is more likely when the people involved have a say in the decision-making process.

The concept of slum upgrading is also examined at length by Robert Werlin (1999). His research examines the role of government in slum upgrading attempts, specifically those influenced by John Turner, in which the government provides a small amount of aid, and in turn,
relies on slum dwellers to gradually improve their own conditions. Turner was opposed to large amounts of government intervention trying to run people’s lives and instead favored a more nuanced approach of removing unsanitary conditions and allowing residents to handle the rest themselves. While at first these strategies seemed to be working, as time went on they appeared less effective. The programs were simply not helping who they were intended to. Some of the impediments have included land ownership, tenure, maintenance, and community participation. Land acquisition is often difficult due simply to the fact that the land is in suboptimal areas and is difficult and costly to upgrade. The tenure issue is often complex, as it is difficult to convince people to pay for services designed to enhance land they do not currently own. Maintenance is another problem, with many of the new facilities that are constructed being of poor quality and unsustainable. The new buildings often deteriorate much faster that well-constructed ones. Community participation is often another challenge. Governments and politicians sometimes exploit slum conditions and upgrading endeavors for their own personal gain. That, coupled with a lack of education, often makes community involvement a difficult proposition. Better government not less government is seen as the key idea for change here as well as combining efforts from the government and the public (Werlin, 1999). One piece of research shows that among slum dwellers in Kolkata 54% were apathetic about finding better housing, yet believe that the government would help them to improve their housing situation (Adhikari, 2014).

A lack of water or toilet facilities across a large area is something that often cannot be resolved by slum dwellers alone and requires additional support and investment from the government or political parties. As Edelman and Mitra (2006) put it, “Political leaders are interested in groups rather than individuals” (p. 26). Early on in slum development, as migrants are settling new land and trying to meet basic needs, political parties often swoop in with “token”
help to gain support during election time. Inferred legality of residence and ration cards are then followed by improvements to infrastructure (roads, water, toilets) which occur slowly if they occur at all. Densely populated slums are prime places for political parties to seek support. Politicians can make minimal improvements and promises, thereby gaining support, and spend very little money in the process (Edelman and Mitra, 2006).

Top-down and bottom-up development strategies, while often seen as an either/or policy choice, should actually not be treated as such. Indeed, a combination of the two may be necessary for progress (Woolcock and Narayan, 2000). This combination of top-down and bottom-up development strategies mirrors the ideas presented decades earlier by John Turner. As previously mentioned, John Turner is one of the seminal theorists in regards to slums and slum development and his writings from nearly 5 decades ago are still worth examining today. Turner (1968) first points out an important distinction among slum dwellers. The very poor, so-called “bridgeheaders” are focused solely on the immediate needs of survival. Food, and a place to sleep are their main concerns. They focus energy on getting and maintaining any work possible, as losing any amount of income would be extremely detrimental. A step up from these bridgeheaders are “consolidators”; these people are not as troubled with mere survival and can live in more permanent residences, hold more permanent jobs and have some savings, and amenities (Figure 1), thereby protecting themselves from the potential disaster of loss of income.
Turner also suggests that to slum dwellers, slums can be seen at least partially as a solution to the inhabitant’s problems. As Turner says “from the government viewpoint, uncontrolled urban settlement is a very serious problem even where it presents no serious or immediate problems for the inhabitants” (p. 118). He also argues that “uncontrolled urban settlement is the product of the difference between the popular demand for housing and that demanded and supplied by institutional society” (p. 120). The supply for housing as determined by the formal sector does not equal the demand of the informal. Conditions are worsened by policies of slum clearing and prohibition of informal settlements. Turner proposes that the technological and legislative resources of the government must be used in conjunction with the initiative and investment capacity of the urban poor to improve the problems surrounding urban housing and settlements. Housing itself must be viewed as more than just a physical structure. Turner views the problems on a more fundamental level than just providing this physical shelter or providing shelter. Turner believes that the poor need not be provided with a modern house, but with opportunities; help finding a job, and a small piece of land to live on will eventually lead to
improved status. The formal and informal sectors are different and separate economically and developmentally, and government agencies must work with the urban poor to mobilize them and facilitate ways for the urban poor to generate their own improvement (Turner, 1968).

This hybrid self-help approach has been attempted with varying degrees of success in Kolkata, India, and other slum areas worldwide. It also ties in with another school of thought that is predicated upon the idea that extremely small scale changes can have profound effects that butterfly outwards. An addition of a bus stop means people congregate there and then stands open nearby to sell goods to those people. One additional streetlight gives children from homes without electricity a place to do homework, enhancing their education. These ideas seek to augment and enhance existing infrastructure in a way that can generate smaller changes over time. Grand changes that do not mesh well with the status quo or that seek to provide whole new environments are not as effective as small changes that allow people to create their own change at their own pace in ways that they decide best benefit them (Hamdi, 2013).

**Social Capital in Slum Settlements**

With this basic knowledge of the slum phenomenon, I was able to look closer at more specific theories and ideas relating to slums. Conceptualizations of slums incorporate the idea of social capital, a sociological construct with broader applications. The concept of social capital is studied intensively by numerous types of social scientists and it has implications that range beyond sociology, planning and geography and into realms of knowledge such as education and economics as well. This economic aspect can be seen on a smaller scale when examined within the context of slums.

Whereas members of the upper class in a society acquire capital in the form of money, poorer members rely on social capital to achieve progress, or at least stave off problems. Despite their less than ideal living and economic conditions, slum dwellers also often have social
networks of friends and relatives residing with or near them acting as a social support system (Hossain, 2008). Social capital, then, is a sort of out-product of social networking. By relying on each other and forming a strong community, the urban poor can work towards a public good and flourish in a society that at a basic level is not set up to benefit them. While non-poor social groups are playing capitalist offense, poor groups are playing defense, struggling to maintain what capital, both social and not, that they do have (Woolcock and Narayan, 2000).

Loss of social capital was cited as a major reason for resistance to change and upgrading in the Indian city of Ahmedabad, where 110 people won a “lottery” to move from their current slum to an area with objectively better housing quality. Of those winners, 34% never even moved into the new residences, and 32% eventually moved back to their original areas, closer to friends and family. The problems that accompany this loss of social capital are summed up succinctly by Barnhardt, Field and Pande (2014) as they state, “The destruction of social capital that comes from reshuffling slum communities is a welfare loss that cannot be so easily rebuilt. Although new ties may be formed eventually, slum relocation programs as they are normally envisioned destroy economically valuable social capital by severing links that may have evolved and strengthened in the neighborhood over decades” (Barnhardt, Field and Pande, 2014, p. 24).

Robert Putnam, one of the foremost scholars in the study of social capital claims that “social capital enhances the benefits of investment in physical and human capital” (Putnam, 1993, p. 2). Working together not only builds trust but has other benefits like fostering innovation. Putnam points out that close knit communities are more trusting. This in turn can spur a local economy and social capital is in a way transformed into financial capital (Putnam, 1993). Putnam (2001) also builds upon the idea that there is something to be gained from networking and social capital when he states “Networks and the associated norms of reciprocity
have value” (p. 1). This is true in even extremely informal connections. A person you merely nod to in a hallway is more likely to help you in a medical emergency situation. That is a very minimal social connection, yet it still provides a benefit. If that connection is multiplied, it stands to reason that a person or group of people you are more deeply networked with would be even more likely to help you on a grander and more formal scale (Putnam, 2001). As Woolcock (2008) puts it, “the most important example of social capital at work in the absence of formal insurance mechanisms and financial instruments, is the use of social connections by the poor, as the primary means of protection against risk and vulnerability” (p. 243). Other research shows this theory in action. In the Ahmedabad study above (Barnhardt, Field and Pande, 2014), slum dwellers who “lost” the lottery and remained in their current homes and situations reportedly had higher levels of help from neighbors and the community during times of need. In instances when major disasters struck, they also received significant aid from their community, whereas those who “won” the lottery and moved to “better” housing, reportedly received no help from their neighbors or community on an informal level (Barnhart, Field and Pande, 2014). While it has been shown that more successful outcomes are achieved in communities with an engaged population (and therefore more social capital), Putnam’s writings point to the continued decline of this type of social engagement in the United States. In a developed and comparatively wealthier country such as the United States, diminishing social capital may not pose any kind of direct or immediate problem. However, in a setting such as a slum in India where most residents are just getting by, a drop in social capital like in the U.S. could be catastrophic. As it is, with that knowledge and with the differences in culture, such a downward shift in India would be unlikely to occur (Putnam, 1995).
Infrastructure and Slum Measurement/Assessment

Beyond an understanding of how, where and why slums are formed, another important objective in the study of slum conditions is to measure and assess their relative status. To this end, my research examines infrastructure. For the purposes of this study, slum infrastructure is represented by the visual indicators used to assess slum conditions; housing conditions, access to water, access to sanitation, and access to amenities. While other examples of slum infrastructure such as pavement and drainage are discussed in the literature, those do not relate specifically to my research.

Access to infrastructure such as water taps and sanitation facilities is a crucial aspect of assessing slum conditions. In areas of limited or inadequate water supply, women and girls are often tasked with acquiring water. This use of time and energy can affect their abilities to participate in other activities, such as participating in economic activities or attending school. Poor sanitation conditions or lack of toilets can lead to sickness and decreased life expectancy (Chandrasekhar, 1981). Access to this type of infrastructure can be contentious as well. For example, in the town of Titagarh, just north of Kolkata, the Calcutta Slum Improvement Programme improved living conditions in the slum by paving the courtyard, providing drainage, providing water taps and building a new toilet block. However, the landlords took offense at how the tenants were using the facility and put a lock on it so that only landlords could use it. The tenants felt that the toilet was built for everyone’s use and it should be accessible to everyone (Das, 2006). This type of questionable ownership and access is a common theme within slum areas. This is also evident in Ghosh’s (2013) case study examining the Bibi Bagan slum in Kolkata. In this example, the Kolkata Environmental Improvement Project (KEIP), which was created by the Kolkata Municipal Corporation (KMC), claims to have addressed issues in 85 slums throughout the city. They claim to have either built or restored 6128 toilets and 604
They also claim to have constructed 39km of sewer lines and 21.75 km of water lines. Within Bibi Bagan, residents were unaware of which local bodies were addressing the local issues. It was not until they saw KEIP on some pavement blocks that they knew who was responsible. The conditions of the shared toilets were extremely poor before the improvements by the KEIP and there were no bathing facilities. Additionally, many of the drains were open, clogged and filled with garbage. After the work done by the KEIP, there were 75 toilets in Bibi Bagan and the conditions are much improved. Urinals and bathing areas were also constructed by the KEIP which has improved satisfaction levels for residents, however there is still a need for more of these types of facilities. Despite improvements, residents still see problems with cleanliness, overflowing toilets and shortages of water and water taps (Ghosh, 2013).

Access to water facilities, sanitation facilities, and other services is not guaranteed for slum dwellers. In Kolkata over 90% of slum dwellers were found to not have their own toilet; 38 people generally shared one toilet, and 88 people shared one water tap (Sengupta, 2010). Research on slums in Colombo, Sri Lanka paints a more depressing picture of slum conditions and infrastructure. In the Gramanoladari slum, residents were forced to wait in long lines to use water taps that were not plentiful enough for the population of the slum. There were also not enough bathroom facilities, and those that did exists were in very poor condition. This lack of infrastructure contributes to a lower quality of life, and surveys conducted in the same slum showed residents with negative opinions and feelings towards both their own home environments and towards their neighbors and other slum dwellers (Subasinghe, 2015).

Bose and Ghosh (2015) surveyed residents regarding infrastructure and living conditions within the slums of Kolkata. The sample included 96 residents across five Kolkata slums. In addition to providing socio-economic data, the results give a sense of the living conditions,
quality of life and infrastructure of the areas. All five slums surveyed had common water taps, yet only one, the E. M. Bypass Area, reported any form of water scarcity. 89.58% of households reported shared sanitation and a high ratio of toilets to people was noted. 36% of people said they saw some form of improvement within the slum in the last 5 years, 47% said they saw no change, and only 17% said they saw conditions getting worse (Bose and Ghosh, 2015).

A tool for assessing relative slum condition is the Slum Severity Index (SSI), which measures the deprivation of a slum or slum residence using United Nations guidelines. These rankings were applied specifically to surveyed households in both Mumbai and Kolkata. The Slum Severity Index assigns a one or a zero as to whether a residence meets slum conditions. Since there are 5 criteria, a 5 meant very poor condition and a score of 0 meant not a slum. Using the UN definitions, much higher slum rates are seen through these responses than the Indian census states. Very few slums in Kolkata (and none in Mumbai) were seen to have an SSI of 5, as most respondents had at least some access to water. Most households were in the 1 to 2 range with Mumbai having a mean SSI of 1.41 and Kolkata 1.22. These numbers do show slum conditions, however those conditions are not on an extremely deprived level (Patel, Koizumi and Crooks 2014). The SSI can also be modified to examine slums at a hyperlocal level.

Janowska, Weeks and Engstrom (2011) also examined slums and categorized them by different levels of vulnerability or severity. Their research focused on slums in Accra, Ghana, and showed that slums are not concentrated into one area of the city, but rather, are spread out across the urban landscape. Geographically Weighted Regression was used to identify a varying relationship across space between slums and levels of vulnerability. The vulnerability of slums themselves does vary and, people who are most vulnerable from a socio-economic standpoint do tend to live in worse slums (Janowska, Weeks and Engstrom, 2011).
In an attempt to measure the quality of life of people living in the slums of Kolkata, Biswas-Diener (2001) surveyed slum dwellers across the city. Participation in the study was voluntary and confidential, and the participants were asked to respond to a series of questions ranking their satisfaction with various aspects of life on a scale of 1 to 7. Many of the findings fell into line with what the researchers believed going into the study, i.e. that slum dwellers would respond negatively about overall life satisfaction, and that life satisfaction correlated with income. However, while respondents reported being unsatisfied with life in general, they also responded positively and expressed satisfaction about their lives when asked to rank their satisfaction in regards to specific aspects of life such as family and friendships (Biswas-Diener, 2001).

Examples also exist wherein indicators are used to analyze quality of life in Indian slums, though not specifically Kolkata. By looking at ten variables that are prevalent within slums, a Quality of Life Composite index was created to determine slum dwellers’ quality of life. The key difference between this work and the research being used here is that survey methods were employed in an effort to determine quality of life (Jha, 2014), whereas this research primarily utilizes visual indicators. There is also existing literature that focuses on shifting perspectives to the positive aspects of slums instead of focusing on the negative. For example, Roy (2011) is concerned mainly with “subaltern urbanism” to explore theories behind slums and megacities and attempts to highlight positive, often unrecognized aspects. The film “Slumdog Millionaire” is examined and discussed for its unrealistic and overly negative portrayal of slum dwellers as “dogs” and as slums as being a place one would want to escape from. Roy proposes four new or relatively new concepts: periphery, urban informality, zones of exception, and grey spaces, and looks at how each of these play a role in understanding and describing slums. Periphery is
viewed as a place that is in between, or a place that is never at the center, yet still a place with potential. Urban informality is seen as rebellion against the system, personal entrepreneurship, and creating a new livelihood for oneself. Zones of exception are defined as “non-contiguous, differently administered spaces” (Roy, 2011, p. 234) that fragment an area. Gray spaces are described as places that lie between the white/legal/approved and the black/destruction/death. These four concepts are, when viewed together, able to give a new perspective on the metonym of slums as well as an appreciation for what they contain and represent (Roy, 2011).

Urban growth and what effect it has on slum infrastructure is an important aspect of the slum phenomenon to consider. Sometimes, growth or urban development is created through a concerted effort from government. In some areas, “new towns” are planned and created on the outskirts of the city. These new towns provide infrastructure for the wealthy who can afford to live there yet do little to nothing to help the poor who cannot. This leads to even further “splintering” between rich and poor where the poor are forced to live in informal settlements with little to no infrastructure that are far more prone to natural disasters (flooding) and other health risks (Rumbach, 2014).

On a global level, some of the most influential recent writing on slums and the potential for quality of life improvements has been done by Janice Perlman, who explored slum life and marginality over a 30-year period in the favelas of Brazil. Her research, which spans four generations of slum dwellers, shows that despite government attempts to get rid of the favelas, over the course of three decades, poor neighborhoods and the number of residents in them continued to grow. Population growth in the favelas far outpaced growth in the rest of the country, except during times when residents were being forcibly removed from the favelas. Originally the growth was mainly due to the influx of new urbanites from the countryside.
Eventually, however, much of the new urban poor were the result of downward social mobility. The research was performed by interviewing residents in 1969, and then attempting to interview the same people 30 years later to see what had changed. Remarkably 307 of 750 original respondents were found three decades later. One of the interesting findings was that 40 percent of favela residents in 1969 eventually went on to rent or own legitimate property by 1999. A more in-depth look at the changing social status of favela residents was done via what Perlman dubs “an index of socioeconomic status” (SES) which measures income, education and living conditions. Interestingly, one of the most significant predictors of upward mobility was community involvement. People who had larger social networks were more likely to move out of and ultimately remain out of the favelas. While there was often little to show monetarily, over the course of 30 years the percent of favela residents with amenities like indoor bathrooms, running water, and electricity increased by nearly double. Illiteracy was also seen to decrease from 45 percent to 29 percent over the course of these three decades. Despite these positive changes, the research does highlight several significant problems to achieving true economic well-being such as job loss, technological advances and less demand for domestic services, drug use, drug violence, and discrimination. The research concludes that no amount of development or upgrading will help the poor if there are no good jobs to help them become better off financially (Perlman, 2006). Furthermore, in related writings and research, Perlman shows that the dividing line between favelas and the formal city sectors is becoming blurred. Favelas now typically have basic infrastructure, the homes are often made of durable material, and they are no longer strictly inhabited by the poor. The main differentiation between favela and non-favela is often simply the stigma associated with living there. Until the 1970’s favelas were not even allowed to be shown on maps, and during that same decade over 100,000 favela residents were forcibly removed and
forced into public housing. Even today many residents of the favelas are so marginalized that they are almost non-human in the eyes of the government. Although observable conditions and access to infrastructure has improved, those living in the favelas often have a bleak outlook due in part to the large amounts of drug violence that occurs there (Perlman, 2005).

**Spatial Analysis in Slums**

As my research focusses on spatial distribution patterns, it is also important to examine other examples and forms of spatial analysis that have been used to examine slums on both local and non-local scales. It is also necessary to look at other potential techniques for spatial analysis that could be applicable.

On a very basic level, simple mapping of slum points can be used for spatial analysis. In this instance, research shows that the distribution of slum points across the city of Dhaka has not been uniform. As expected, slums are concentrated on the periphery of the city. Clustering is observable in certain geographic areas of the city, but also in certain areas near rivers and railways. This research shows that the slum settlements in Dhaka are distributed in a scattered manner, and that the average slum size is a rather small 0.37 acres (Arifeen, and Mahbub, 1993). Some research even attempts to use patterns observed from high resolution remote sensing imagery to examine the “urban tissue” and reveal potential locations of urban poverty. Different textures can be observed across slums and entire cities that show different levels of density and urbanization and potentially levels of poverty (Barros Filho and Sobreira, 2005).

Research undertaken in Delhi examined the spatial distribution of slums across the city. Slums in Delhi are often found along roads, near river embankments, or in other low lying areas where the threat of eviction is lower. Per this research, distribution of slums across the city is variable across different parts of the city. The South Zone had the highest concentration of slum settlements, followed by the North, West, East, and finally Central Zone which had the lowest
concentration. The Central Zone is home to many controlled, and organized developments. In turn, it has less open space that would be suitable for slum inhabitation (Ishtiyaq, M., & Kumar, 2011).

Other research has been done to spatially analyze urban growth, specifically in Kolkata. Bhatta, (2009) analyzed growth and expansion via satellite images of Kolkata-Howrah from 1975, 1990, and 2005 under the context of quantifying urban growth. The research used Pearson’s chi-square test and Shannon’s entropy method to calculate degree of freedom, degree of sprawl, and a newly created metric “degree of goodness.” This is a highly quantitative and mathematical approach, and while it does not directly examine informal settlements themselves, does provide high quality information about the expansion of the study area. Over the three decades examined, expansion was measured in all directions and statistical models were used as a new approach to show that unsustainable urban growth and expansion are occurring (Bhatta, 2009).

Previously, spontaneous settlements (slums) were viewed as isolated structures within the already chaotic framework of a developing-world city. Barros and Sobreira’s research uses models to show that spontaneous settlements are evolving via a process and pattern. These settlements can be seen as “pockets” which in a way act as stabilizers of the city as a whole (Barros and Sobreira, 2002). In Rio de Janeiro, the way favelas evolve defies most generalizations. The distribution of favelas across the city does not conform to urban spatial models. In Rio de Janeiro specifically, the physical structure of the city and its landscape play a large role. The complexity of the city itself leads to many favelas not being concentrated on the periphery, but instead more interwoven into the framework of the existing city structure. Favela size and population do not correlate with distance from the city center, however; while older and
higher quality favelas do tend to be more centrally located, new favelas do tend to be more peripherally located (O’Hare and Barke, 2002).

Autocorrelation techniques can be utilized to examine where concentrations of negative social indicators, and in turn, slums are located. Using census data, Moran’s I can be utilized on a broad level to determine potential problem areas, but more local statistics are needed and used to determine more specific problematic locations. For example, a Getis-Ord function can be used to show areas with a high autocorrelation of low education levels (Murgante, Las Casas and Danese, 2008).

The use of more local statistical methods is a relatively newer phenomenon. Research existed that examined slum placement within a city, however, there was a need for tools that can assess variation within a slum at a local level. Technological advances over the past 20 years allow for the use of more specific spatial analysis techniques. With the increasing number of large data sets, along with new technological capabilities provided by the advancement of GIS, a demand has been created for new spatial analysis techniques. Previously, spatial data analysis was based on global statistics such as Moran’s I and Geray’s C, but recently a focus has shifted towards local patterns (Anselin, 1995). The G family of statistics introduced by Getis and Ord (1992) provide the advantage of being able to analyze spatial association at a local level. This was an advancement beyond the global method of Moran’s I that was used predominantly previously. When this new family of statistics is applied locally, new “pockets” or HotSpots are detectable that show correlation that would not have been seen using a global statistic. This local statistic measures “the degree of association that results from the concentration of weighted points (or area represented by a weighted point) and all other weighted points included within a radius of distance d from the original weighted point (p. 190).” This allows for the examination
of spatial association at multiple levels, in a single observation, or across an entire sample (Getis and Ord, 1992).

Beyond the Getis-Ord G family of statistics, Anselin’s advancements allow for global techniques like Moran’s I to be used on a local level. These new techniques allow for cluster and outlier analysis on a more local scale. Local patterns are often not picked up by global indicators. Having a local measurement that relates to a global statistic allows for the analysis of outliers and influential observations that are not possible with Getis-Ord Gi* statistics (Anselin, 1995).

**Literature Review Conclusion**

The literature I have reviewed spans a significant base of knowledge regarding the existence and growth of slums, slum redevelopment, and slum infrastructure in Kolkata, Asia, and worldwide. Living conditions, quality of life, and severity are all examined, however, there is a bias toward research and literature on slum policy and slum upgrading and this abundance is evidenced in the levels of literature reviewed in my research. Similarly, social capital is also widely recognized and applied. Additionally, the central idea of infrastructure in my research and my research questions leads to an emphasis on literature of that ilk, with measurement of infrastructure also standing out as a relevant focus. Some of the more important and relevant literature is highlighted below (Figure 2).
Selected Literature

- Theories of Slum Formation and Slum Growth
  - Lee (1996)
  - Ravenstein (1889)
  - Hossain (2008)
  - Stokes (1962)

- Policies for Slum Redevelopment and Upgrading
  - Andavarapu and Edelman (2013)
  - Ghosh and Ghosh (2011)
  - Werlin (1999)
  - Turner (1968)

- Social Capital in Slum Settlements
  - Woolcock and Narayan (2000)
  - Barnhart, Field and Pande (2014)
  - Putnam (1993, 2001)

- Infrastructure and Slum Measurement/Assessment
  - Bose and Ghosh (2015)
  - Patel (2014)
  - Roy (2011)
  - Perlman (2005, 2006)

- Spatial Analysis in Slums
  - Bhatta (2009)
  - O’Hare and Barke (2002)
  - Anselin (1995)
  - Getis and Ord (1992)

Figure 2. Selected Literature.
The literature on slums, while vast, is not all encompassing. There are gaps in this knowledge that my research attempts to fill. Research utilizing GIS and spatial analysis techniques is certainly less prevalent than the other areas of study and research mentioned above, particularly at a more localized scale. The use of spatial analysis regarding slum conditions is a still expanding field especially at a very local slum level. My research seeks to add to the existing literature and research on the subject and provide a new methods and perspectives for spatially analyzing slums at a local level.

My research, and the use of GIS and spatial analysis using visual indicators, can be used to analyze conditions in a single slum. Through this, new conclusions can be reached as to why a slum is structured as it is, and what that information may mean for slums as a whole.
CHAPTER THREE
DATA AND METHODS

In this section I outline the data and methods used to complete my research objectives and answer my research questions. First I delineate, explain, and present the study area of Rajarghat. Second, I outline the development of the visual indicators used to analyze the condition of the slum. I then explain the procedures for gathering the primary data in Rajarghat and conclude the section by explaining the geographic and geoprocessing techniques used to spatially analyze the gathered data.

Case Study of Rajarghat

Rajarghat is located in the mega-city of Kolkata in eastern India’s province of West Bengal (Figure 3). Rajarghat is a low income informal settlement, or slum, in eastern Kolkata with a population of 10,189. The slum is in close proximity to a large garbage dumping ground which provides a majority of the residents with their occupation of “rag picking.” Rag picking basically consists of the aggregation, segregation, and processing of trash and recyclable materials. This type of employment and work belongs to the informal sector, in that they are not recognized in any official capacity. Yet this nevertheless benefits the city in its waste management efforts. In addition to its proximity to the garbage dumping facility, some other relevant geographic aspects of Rajarghat are the main road (DC Dey Rd) that runs through the northern portion of the slum, the canal that forms the slum’s northern border, and the vacant land to the east of the current slum area (Figure 4). There is also another secondary road or thoroughfare that traverses the slum from the northwest to southwest corners, but would not be considered a major artery.
Figure 3. Location of Rajarghat in relation to Kolkata/Hooghly River.

Figure 4. Map of Rajarghat showing canal, main road, and vacant land.
Due to its proximity to several major arteries and transportation hubs, Rajarghat is in an advantageous location that seems to contradict its modest land use. When Rajarghat first began developing, however, the area was an almost forgotten place near the Kolkata wetlands that would generally not be of use or interest to more formal parts of the city. At its inception then, the area of Rajarghat would have been a prime location for rural to urban migrants, and in fact, still is. Even though Rajarghat was not, and is not, ideal, it was and is likely better than the alternatives of living in an undeveloped rural environment. Initially, there would have been little to no threat of eviction and there was vacant land that informal structures and settlements could be built upon. The area was still relatively close to the urban center of Kolkata and therefore was an area that people migrated towards in large numbers, thereby creating the settlement that has grown into the Rajarghat we see today.

Government entities including the KMC have attempted slum upgrading and other potentially helpful infrastructure related projects in the area, however those were met with mixed success. Several five story apartment buildings were constructed on the edge of Rajarghat (Figure 5). Preliminary observations of the new structures revealed that the structures did not yet have drinking water. Dwellers also reported difficulty in paying living expenses, difficulty climbing the stairs, and poor construction quality of the buildings overall (Okey et al, 2016).

*Figure 5. Attempts at slum upgrading in Rajarghat, photo credit Nihal Singh Verma (Okey et al, 2016).*
There are examples of social capital in Rajarghat that go beyond the communal nature of the rag-picking economy. The community of Rajarghat itself is tight knit. The residents are happy and would most likely not want to leave if given the opportunity (Okey et al, 2016). When this is viewed alongside the reluctance of residents to move into the new apartment buildings provided for them, it is apparent that the social capital garnered from the sense of community and networking amongst residents is of great importance. The residents of Rajarghat may not have large amounts of monetary capital, but social capital among them can be viewed as having a positive impact.

To this point, infrastructure measurement, slum analysis, and spatial analysis have not been undertaken in Rajarghat. My research will fill the gaps in research by examining all of these concepts locally, within the slum. Starting with data collection, I will develop four indicators of slum conditions. I will then utilize GIS to characterize spatial distributions and patterns of those indicators. Finally, I will create an aggregate index of adequacy to measure and describe slum conditions in a way that can be compared to other slums (Figure 6).
Development of Slum Condition Indicators

Using visual observation and GPS (Garmin GPS Map 64s), observation samples were recorded for three types of data points: 1) houses, 2) water taps, and 3) sanitation facilities. The data gathered from these observations was used to develop the four indicators used in my research. In my research, 81 houses, 23 water taps, and 32 sanitation facilities were sampled and had data gathered on them. Additionally, the geographic locations of 21 water taps and 27 sanitation facilities were provided by IIT field assistants. A total number of 44 water tap
samples, and 59 sanitation facility samples comprise the sample analyzed in my research. From these observational samples, I developed four indicators of slum conditions. The indicators that I developed to assess slum conditions are 1) housing condition, 2) access to water, 3) access to sanitation facilities, and 4) access to amenities.

**Housing Conditions**

The housing condition indicator assesses slum conditions by determining a level of permanency for each housing structure. There are three possible levels of permanency for each house. To concisely define the levels of adequacy regarding housing structure, this metric is used:

![Figure 7. Housing adequacy metric.](image)

Level 1 adequacy: Both roof and walls are made of non-permanent materials (figure 8)

Level 2 adequacy: Walls are made of permanent material; roof is made of non-permanent material.

Level 3 adequacy: Both walls and roof are made of permanent materials.

N/A: A home with non-permanent walls and a permanent roof, is structurally impractical and was not encountered.
Level one adequacy houses are considered to be non-permanent. Level two and three adequacy houses are considered to be permanent, as they have at least one permanent feature. Within the confines of my research, a house having permanent walls is defined as being a house with

<table>
<thead>
<tr>
<th>Point Number (Group number, Observation number)</th>
<th>Housing Type</th>
<th>Pictures of Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>3, 18</td>
<td>Permanent walls/permanent roof</td>
<td><img src="image1" alt="Permanent walls/permanent roof" /></td>
</tr>
<tr>
<td>3, 2</td>
<td>Permanent walls/non-permanent roof</td>
<td><img src="image2" alt="Permanent walls/non-permanent roof" /></td>
</tr>
<tr>
<td>3, 3</td>
<td>Non-permanent walls/non-permanent roof</td>
<td><img src="image3" alt="Non-permanent walls/non-permanent roof" /></td>
</tr>
</tbody>
</table>
cement, concrete, or brick walls. Any other building material such as, bamboo, wood, plastic, or corrugated metal is considered to be a non-permanent wall. A house having a permanent roof is defined as being a house with a cement, concrete, or brick roof. Any other building material such as, bamboo, wood, plastic, corrugated metal is considered to be non-permanent (Figure 8). Roofing tiles (ceramic or otherwise) are considered to be a non-permanent roof.

**Access to Water**

The access to water indicator assesses slum condition by determining what areas of the slum are within 100 feet of a water tap (Figure 9). As 100 feet is the average amount of time a person can walk in 30 seconds, this is here considered as reasonable access to water. Quality of water was not examined as part of access to water, only the distance to a water tap is examined.

**Access to Sanitation**

Similar to the access to water indicator, the access to sanitation indicator assesses slum condition by determining what areas of the slum are within 100 feet of a homemade toilet (Figure 10 or sanitation facility (Figure 11). For the same reasons, being within 100 feet of a sanitation facility, is considered having access to sanitation. Again, the quality of sanitation facilities is not examined here, only distance to a sanitation facility is examined.

**Access to Amenities**

Review of the observations for the other indicators led to the development of a fourth indicator of slum conditions, access to amenities. Visual observations showed the presence of multiple satellite dishes (Figure 12) and locking toilet structures (Figure 13) across Rajarghat. Ownership of, and proximity to, these types of amenities signifies a higher standing within the community. Therefore, the locations of these types of amenities can also be used to assess the slum conditions.
Figure 8. A fully non-permanent house.
Figure 9. A water tap.
Figure 10. A toilet structure over the canal.
Figure 11. A cement sanitation facility.
Figure 12. A house with a satellite dish.
Figure 13. A locking sanitation facility.
For the housing condition indicator, 82 of 2,613 houses were surveyed, or 3% of the houses in the slum. For the access to water indicator, 44 water taps were located. The area of the slum is 733,956.6 sq. ft. therefore one water tap was located for every 16,680.8 square feet of slum area. For the access to sanitation indicator, 59 sanitation facilities were located. The area of the slum is 733,956.6 sq. ft. therefore one water tap was located for every 12,439.9 square feet of slum area.

**Data Collection**

Primary data collection for my research occurred in Rajarghat, a slum located in the eastern fringe of the Kolkata metropolitan area. Data collection took place the first week of June 2016 and was a collaborative effort between students and faculty of both Indiana University of Pennsylvania and Indian Institute of Technology Kharagpur. Prior to sampling, some preliminary base mapping was undertaken by colleagues from IIT. Data was collected exclusively by visual observation While in the slum, GPS devices (Garmin GPS Map 64s) were used along with photographic and written documentation to identify, count, and record data on housing conditions, and locations of and access to water and sanitation facilities.

The research group was divided into three smaller teams of three to four observers for the purpose of primary data acquisition: two groups would analyze housing conditions and the third group would be looking for shared water sources and bathroom facilities. Each group had a GPS user, a photographer, a writer, each from IUP and a guide from IIT Kharagpur.

To achieve a random sample, the groups examining housing condition started on the right side of the street and assessed every 10th house. If the group came to an intersection, a coin was flipped, heads meant turn right; tails meant turn left. After each assessment, the group switched sides of the street, and repeated same process, analyzing each 10th house with the same coin flip.
turn determination. The groups continued switching sides and repeating this process. A second group, led by myself, went back to the slum two days after initial data collection to get more data points and ensure that all areas of the slum had been covered using the same method.

Three variables were measured for each house, entered into the GPS unit, and written down:

Variable 1: presence of personal water tank or no water tank

Tank = T  No Tank = N

Variable 2: wall material

Permanent = P  Not Permanent = N

Variable 3: roof material

Permanent = P  Not Permanent = N

GPS number and observation number were also entered for each residence. An example of an observation string would be: 1_1_N_P_P. This would signify GPS Unit 1, observation 1, no tank, permanent walls, permanent roof.

The writer also wrote this down, along with any other interesting yet brief observations about the house. The photographer took a picture of each home, making sure to capture walls, roof and water tank if applicable.

The third group looked at shared water sources and bathroom facilities. Using the slum maps containing preliminary data gathered by the IIT team, this group attempted to visit every shared toilet facility and water tap in the slum to get an accurate GPS reading and two photographs of the water tap or shared bathroom.

While canvassing the slum, the GPS user entered the following into the GPS unit for each

---

2 No water tanks were located and this variable was not used in my research.
location: the GPS number, the observation number, and whether it was a water tap or toilet facility. An example of an observation string would be: 1_1_W. This would indicate GPS unit 1, Observation 1, Water tap.

The writer also wrote this down, along with any other interesting yet brief observations. The photographer took two pictures of each location preferably from two different angles.

Unfortunately, due to time and manpower constraints, the entire slum could not be canvassed in one day, however a large and well dispersed area was. A second group went back to the slum two days after initial data collection to locate more data points and ensure that as many areas of the slum had been covered as possible. Using what is walkable in 30 seconds as a baseline, 91% of the slum (668,346.3 of 733,956.6 sq ft) falls within 100 feet of a sampling point of any kind and this can be considered the survey area within the broader study area (Figure 14).

After the data was collected, all the information was imported and/or manually entered into spreadsheets for preliminary evaluation. All the GPS data was imported directly into excel spreadsheets and condensed into a file containing all housing points, and a file containing all water tap and toilet points. The writer’s string observations were cross-referenced with those entered into the GPS to maintain accuracy. The writers’ notes were all manually entered into spreadsheets as well to have documentation of each location. All photographs were imported and renamed to match the observation numbers of the locations that were photographed. The photographs were all double checked and all matched up to the correct locations. The data that was contained within the housing spreadsheet and the water and toilet spreadsheet was imported into ArcGIS to be analyzed further. Preliminary data collection by the team from IIT Kharagpur in the weeks preceding the primary data collection was also used to augment this primary data.
Figure 14. Area of slum sampled.
Figures 15 and 16 display all points surveyed. It is also important to note that interactions with slum residents were not a part of this data collection process.

*Figure 15.* All housing points.

*Figure 16.* Locations of water taps and sanitation facilities.
After importing the x,y point data showing the locations of each recorded house, water tap and sanitation facility, I added columns to each set of data to also indicate which structures also had satellite dishes and/or locking toilet structures. The information about each was contained in both the pictures and the written accounts, but not coded on the GPS units in the field. I then plotted all the points gathered during our primary data acquisition trips onto a map of Rajarghat along with the existing points provided by the team at IIT Kharagpur. Each type of indicator or structure was symbolized appropriately for easier identification on the map which now contained data on each recorded house, water tap and sanitation facility.

**Spatial Analysis**

Spatial analysis techniques were utilized to examine each of the four indicators that I had previously developed and collected data on.

For the housing conditions indicator, I wanted to examine whether there were any patterns evident in the distribution of non-permanent houses. Due to its wide usage and prominence in the statistical geographic community, the first method I used to look into spatial autocorrelation was using the Moran’s I statistic. Moran’s I is a tool that can be utilized to determine whether a set of points is distributed in a random or non-random way. When calculations are complete, a Moran’s I score near +1 is evidence of a strong pattern, or high level of positive spatial autocorrelation, a Moran’s I score near -1 is evidence of a strong negative autocorrelation, while a score near zero indicates no spatial pattern, or a random distribution. For the purposes of my research, however, Moran’s I did not end up being an effective tool for discovering spatial patterns. The reason behind this is that Moran’s I is a global statistic, a very general tool used to show whether a pattern exists that is not random. Thankfully, Spatial Analysis is an ever-expanding field and there are many new tools that can be, and are, more
effective. For the purpose of my research, local statistics would be more beneficial to ascertain whether there is any type of clustering of points in a more specific location or if there are any hotspots of condensed activity (Rogerson, 2010).

The first local statistic tool I employed was the ArcGIS HotSpot Analysis (Getis-Ord Gi*) tool. When features are inputted, this tool identifies HotSpots and ColdSpots that are statistically significant. ArcMap displays both HotSpots and ColdSpots of 90%, 95%, and 99% confidence as well as points that are not statistically significant (ESRI, 2014). In my research, I used this tool to determine if there are hotspots of houses that are fully non-permanent amongst all house points that were gathered. In conjunction with the ArcGIS HotSpot Analysis (Getis-Ord Gi*) tool, I also utilized the Local Moran’s I statistic. In ArcMap, this is referred to as Cluster and Outlier Analysis for the obvious reason that it is used to identify and measure spatial clustering or outliers in sets of data. The tool displays both high and low level clusters and outliers as well as points that are not statistically significant (ESRI, 2014). In my research, I employed this tool for the same purposes that hotspot analysis was used to see if similar results were achieved. I used both tools to see if the results were similar, which they were, but I also applied both tools due to their differences. Getis-Ord Gi* allows for the measurement of the association of a concentration of points (Getis and Ord, 1992). Anselin’s Local Moran’s I, being connected with a global statistic, allows for analysis not possible with Getis-Ord Gi*, including the analysis of outliers and influential observations (Anselin, 1995). For examining spatial correlation and patterning in a smaller scale setting, these local statistic tools are extremely useful, especially when and where global statistic tools are not (Rogerson, 2010).

For the access to water indicator, I wanted to analyze the distribution of water taps slum wide, specifically to see if they appeared to be consistently distributed throughout the slum and
within close distance to the entire population. To accomplish this, I created a 100-foot circular buffer around each water tap. After creating the buffers, I then dissolved the resulting overlapping circles into a single large polygon and clipped that polygon to the slum border. This left a polygon within the slum to show which areas were within 100 feet of either a water. By calculating the polygon area and comparing that to the area of the slum, and/or the survey area, I could determine what percentage of the area was within 100 feet of a water tap or sanitation facility. This was also done with buffers of 50 feet and 200 feet to see the variations in the results. For the second and third set of buffers I created a model (Figure 17) in ArcMap to streamline the buffer/dissolve/clip process. The attached model is for clipping a dissolved 50-foot buffer to the Rajarghat Slum border. This admittedly simple model is included here and could be used and reproduced to achieve similar results when studying access to infrastructure in a different slum. By simply changing the buffer length (and the clip area if studying a new area) the model can be run repeatedly to show different results.

Figure 17. A model used to streamline the buffer/dissolve/clip process.
For the access to sanitation indicator, I utilized the same methods and techniques as I did for the access to water indicator. However, I obviously used the location of each sanitation facility as a starting point instead of each water tap.

For the access to amenities indicator, I wanted to examine whether there were any patterns evident in the distribution of structures with satellite dishes and of locking toilet structures. Similar to the housing conditions indicator, I first attempted to utilize Moran’s I, but for the same reasons, that statistic was found to not be effective and I again progressed to using more local statistics. I again used the ArcGIS HotSpot Analysis (Getis-Ord Gi*) tool in conjunction with the Local Moran’s I statistic to ascertain any patterns, HotSpots, or clustering on a local level.

While developing the index of adequacy I also employed the Kernel Density tool in ArcMap to analyze proximity and access to the four indicators of slum conditions. For example, running the tool on the existing permanent housing points calculates and displays the density of features in an area around a given cell. Cells that are in close proximity to a permanent house will have a high value, and cells that are not near will have a low value or no value (ESRI, 2014). To achieve uniformity across all kernel density maps, default settings were used and area was calculated in square map units.

**Development of the Index of Adequacy**

In addition to developing indicators of slum conditions, my research also sought to develop an index of adequacy to assess slum conditions. The index of adequacy incorporates all four indicators of slum conditions as well as people per household. This index could be used to compare slum areas and potentially and eventually be used to guide policy decisions. For example, it would be foolish to allocate funding for sanitation/toilet facilities in a slum
community where 98% of the area, people or households already had access to those facilities. The product of this index of adequacy is twofold. The first output is a series of kernel density maps (Figure 18) that show access to permanent housing, water, sanitation, and amenities (satellite dishes, and locking toilet structures). Second is a table that delineates access to durable housing, access to water, access to sanitation, and people per household for Rajarghat. The methodology for these maps and this table can be used in other slum settlements and the results compared with those found in Rajarghat.

Developing an Aggregate Index of Adequacy

![Figure 18. Kernel density maps.](image)
The second portion of the index of adequacy is the table that delineates access to durable housing, access to water, access to sanitation, and people per household for Rajarghat. For this table, access to durable housing is defined as all houses that are of levels two or three adequacy. Access to water is defined as being within 100 feet of a water tap. Access to sanitation is defined as being within 100 feet of a sanitation facility. People per household is simply the average number of people per residence slum wide.
CHAPTER FOUR

RESULTS AND DISCUSSION

This section is organized into three parts. Each part will answer one of the research questions postulated in this research.

The Slum Conditions in Rajarghat

Of the 82 houses surveyed in Rajarghat; 63 (77%) had permanent walls and non-permanent roofs; 17 (21%) had non-permanent walls and non-permanent roofs; and 2 (2%) had permanent walls and permanent roofs (Table 2).

Table 2

<table>
<thead>
<tr>
<th>Housing Structure</th>
<th>Number of Houses</th>
<th>Percent of Houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent walls/permanent roof</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>Permanent walls/non-permanent roof</td>
<td>63</td>
<td>77%</td>
</tr>
<tr>
<td>Non-permanent walls/non-permanent roof</td>
<td>17</td>
<td>21%</td>
</tr>
</tbody>
</table>

There were a few “mini-clusters” of homes without permanent walls or roofs. In general, those structures and clusters of structures appeared to be spread out across the entire area of the slum, including a cluster in the northeast corner. Distribution of housing types overall can be described as random with some small clustering (Figure 19). Two fully permanent houses were observed in my research are located just to the northeast of the center of Rajarghat. This is noteworthy for a very specific reason. When previous land use maps are examined it can be seen that these two houses are located on land which previously served as a playground, or vacant space (Figures 20 and 21). It can then be inferred that these fully permanent cement houses were built more recently and after the majority of slum construction.
Figure 19. Houses sorted by building material.
Figure 20. Fully permanent houses.

Figure 21. Land use map 2011. Source (Sen 2011).
Water taps seem to be more than sufficient for the population. Along some of the main paths in the slum interior, water taps were found approximately every five houses. Private/homemade toilet structures (or ones that had not been built by the KMC) were found commonly along the canal, most likely for the convenience of waste going directly into the water despite potential health concerns. The overall number of toilet facilities, while not overly abundant, did seem to be sufficient for the population of the slum. There were few if any observable lines of people waiting for either water or toilet facilities which would further indicate an adequate number of each facility. Other than the non-KMC toilets near the canal and the water taps along certain main “roads,” water taps and toilets also are relatively evenly distributed throughout the slum. This can be seen even more clearly by viewing the water tap and sanitation facility locations generated firsthand in my research in conjunction with the locations documented in the preliminary survey by the IIT team (Figure 22).

The mere existence of dozens of public water taps and sanitation facilities suggests that all residents of Rajarghat have access to these facilities. However, my inability to document every water tap and sanitation facility complicates the analysis and interpretation of my findings. With the use of the primary gathered data along with the previously gathered data from the IIT team, however, we can paint at least a semi-complete picture. Also, since it is not technically defined, for the geographic purposes of my research, access to water and toilet facilities are defined as living within 100 feet of a water tap or toilet facility of any kind. By using ArcGIS and running a buffer operation of 100 feet around each water tap and toilet facility, and then dissolving those buffers into single polygons (and then clipping those polygons to the slum border), one can display all areas of Rajarghat that are with 100 feet of a water tap or sanitation
Figure 2. All water taps and sanitation facilities.
facility (Figures 23 and 26). I also ran buffers to show what areas of the slum were within 50 feet (Figures 24 and 27) and 200 feet (Figures 25 and 28) of a water tap or toilet facility. The decision was made to continue analysis with the 100-foot buffer due to the fact that it takes approximately 30 seconds to walk 100 feet. I feel that under these circumstances, 30 seconds is an acceptable amount of time to walk to reach these amenities. A distinct majority of the residential areas of Rajarghat are within 100 feet of both amenities and that is without taking into consideration any undocumented water taps or toilets. Even looking at the entirety of the slum, it is clear that most locations are within 100 feet of a water tap and toilet facility. The question is: exactly how much of the slum? Per the Slum Boundary on ArcGIS, the area of the Rajarghat slum is approximately 733,956.6 square feet. The area of the survey area is 668,346.3 square feet. The area within 100 feet of a water tap is approximately 538,190.1 square feet, and the area within 100 feet of a sanitation facility is approximately 557,422 square feet. This means that by land area, approximately 73% of Rajarghat is within 100 feet of a water tap and approximately 76% of Rajarghat is within 100 feet of a sanitation facility. 3 This also means that 81% of the survey area is within 100 feet of a water tap and 83% of the survey area is within 100 feet of a sanitation facility. Even without all water and toilet locations marked, it is safe to say that the majority of Rajarghat has access to these amenities and these numbers (or preferably more complete ones) can be compared with those of other areas.

3 For reference, the area of the slum within 50 feet of a water tap is approximately 250307.2 square feet, and the area of the slum within 50 feet of a toilet facility is approximately 277693.8 square feet. This means that by land area, approximately 34% of Rajarghat is within 50 feet of a water tap and approximately 38% of Rajarghat is within 50 feet of a toilet facility. The area of the slum within 200 feet of a water tap is approximately 691742.7 square feet, and the area of the slum within 200 feet of a toilet facility is approximately 693990.2 square feet. This means that by land area, approximately 94% of Rajarghat is within 200 feet of a water tap and approximately 95% of Rajarghat is within 200 feet of a toilet facility.
Figure 23. 100 foot water tap buffer.

Figure 24. 50 foot water tap buffer.
Figure 25. 200 foot water tap buffer.

Figure 26. 100 foot sanitation facility buffer.
Figure 27. 50 foot sanitation facility buffer.

Figure 28. 200 foot sanitation facility buffer.
Beyond housing conditions and access to water and sanitation facilities, there were several other notable findings from the field observations. Electrical service was observed in all areas of Rajarghat; this may have included illegal connections. Satellite dishes were present on five houses as well as on four toilet/bathroom structures. Since toilet structures with satellites are obviously only being used for their structural integrity and are affiliated with a nearby house, for the purposes of my research, structures with satellites will all be grouped together and examined as a single entity rather than houses with satellites and toilet structures with satellites. Of the nine structures with satellite dishes, five are clustered in the northeast corner of Rajarghat. The other four structures with satellite dishes were in a cluster in Rajarghat’s southwest corner (Figure 29).

Seven locked or enclosed toilet structures were also observed. These types of toilet structures indicate that the facilities within are most likely for private or personal use and may signify a higher standing within the community that affords more privacy and restriction of use. Five of the seven locking or private toilet structures were also clustered in the northeast corner of Rajarghat, nearby to the main access road, the storm water outlet canal, and the cluster of structures with satellite dishes. Of the remaining two locking or private toilet structures, one was located in the same southeastern corner which contained the four structures with satellite dishes and the other was located in the east/central part of the slum (Figure 30).

**Spatial Patterns of Slum Condition Indicators**

Using the spatial autocorrelation tool Moran’s I revealed no distributions that were significantly different from random when used to examine the clustering and dispersion of non-
Figure 29. All structures with satellite dishes.

Figure 30. Structures with locking or private toilets.
permanent houses, structures with satellite dishes, and locking/private toilet structures. The specific results of Moran’s I are found in Table 3.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Non-permanent Housing</th>
<th>Structures with Satellite Dishes</th>
<th>Locking Toilet Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moran’s I Value</td>
<td>0.049362</td>
<td>0.005557</td>
<td>-0.023034</td>
</tr>
<tr>
<td>z-score</td>
<td>0.518121</td>
<td>0.197424</td>
<td>-0.195686</td>
</tr>
<tr>
<td>p-value</td>
<td>0.604374</td>
<td>0.843496</td>
<td>0.844856</td>
</tr>
</tbody>
</table>

These results are evidence of a distribution of points that is not statistically different from random. This is due to the global nature of the Moran’s I statistic. When the local statistical tools Anselin Local Moran’s I and HotSpot Analysis (Getis-Ord Gi*) were utilized, significantly non-random distributions were found for all three variables.

Using HotSpot Analysis (Getis-Ord Gi*) in ArcGIS displays HotSpots for non-permanent housing in the northeast portion of the map (Figure 31). As is evidenced by that figure, the northeast corner of Rajarghat is a significant HotSpot for completely non-permanent houses. The HotSpots displayed in that corner are within the 99% confidence range meaning they have a very high statistical significance, which is considerably higher than the lone 90% confidence HotSpot in the more central area of the slum. All other areas of the slum were not statistically significant hot (or cold) spots. The results generated from the use of the Anselin Local Moran’s I tool reinforce the HotSpot results for the most part (Figure 32). High levels of clustering for non-permanent houses are again found predominantly in the far northeast corner of the slum. Anselin
Figure 31. HotSpots of non-permanent houses.

Figure 32. Clustering of non-permanent houses.
Local Moran’s I also reveals a high-level cluster near the center part of the slum as well as a statistically significant outlier area in the southeast portion of the slum.

Using HotSpot Analysis (Getis-Ord Gi*) in ArcGIS displays HotSpots for structures with satellite dishes in the northeast portion of the map as well as a HotSpot in the southeast portion (Figure 33). In the northeast portion, there is one 90% HotSpot and one 95% HotSpot in addition to the two more statistically significant 99% confidence HotSpots. The HotSpot in the southeast portion falls in the middle range as far as statistical significance goes at 95% confidence. Anselin Local Moran’s I confirms these findings and displays two areas of statistically significant clustering in the northeast corner of Rajarghat. These results also show significant outlier areas in the southeastern corner, adjacent to the secondary road of the slum (Figure 34).

Using HotSpot Analysis (Getis-Ord Gi*) in ArcGIS displays multiple levels of HotSpots for locking toilet structures in the northeast portion of the map. These hotspots are slightly further towards the central north portion of Rajarghat rather than the extreme northeast (Figure 35). This straying towards the center is also depicted in the statistically significant clustering that is found with the use of Local Moran’s I (Figure 36).

**Index of Adequacy Assessment**

The findings generated from my research can be used to create the “index of adequacy”. While firsthand observations can provide anecdotal evidence that the number of water taps and toilet facilities are adequate for the population, further analysis provides a measurable basis for comparison. The SSI (Slum Severity Index) (Patel, Koizumi and Crooks 2014) mentioned earlier in my research can be modified to help create an “index of adequacy” to better assess whether Rajarghat has an adequate number of taps and sanitation facilities; whether
Figure 33. HotSpots of structures with satellite dishes.

Figure 34. Clustering of structures with satellite dishes.
Figure 35. HotSpots of locking or private toilets.

Figure 36. Clustering of locking or private toilets.
housing structure is adequate; whether there is adequate space per person; and how these numbers compare to cases elsewhere.

As mentioned previously, permanent housing is defined as houses that are of level two or three adequacy. Access to these permanent houses are measured with the use of the ArcMap kernel density tool. This tool produces a map that shows darker colors, for higher kernel values, in areas that are near to permanent housing. All cells in the map are then reclassified to show kernel values on a scale of 1-10 with 10 being the highest value (Figure 37).

Access to water is measured in the same fashion as permanent housing. Again, the kernel density tool is used to create a map displaying kernel values 1-10 for areas around the slum based on their proximity to a water tap (Figure 38). Access to sanitation is measured in the same way, with the basis for access being the points on the map of all sanitation facilities. The kernel density tool is used here to create a map displaying kernel values 1-10 for areas around the slum based on their proximity to a sanitation facility (Figure 39). The maps displaying access to water and sanitation facilities unfortunately display gaps which may not necessarily indicate a lack of water or sanitation access. Even with a group returning on a second day, the entire slum was not able to be surveyed. Due to time and manpower constraints, as well as the nature of the random sampling method utilized, there were several areas, or pockets, of the slum which were not visited or sampled in my research. These unvisited areas can be seen when looking at the plotted points for all houses and all water taps and sanitation facilities and the associated buffer map. These areas may have access to water and sanitation, and the maps showing low values there could be due to the sampling methods not allowing for data collection in those locations.
Figure 37. Permanent housing kernel density map.

Figure 38. Access to water kernel density map.
Access to amenities is measured and displayed in a similar way but with a key difference. Access to amenities is one indicator, however there are two types of amenities that were measured. A kernel density map was made for proximity to satellite dishes as well as for locking toilet structures. These two maps were then combined using the map algebra tool to produce a single kernel density map displaying kernel values 1-10 for areas around the slum based on their proximity to amenities (Figure 40).

These kernel density maps delineate and display areas of Rajarghat that have higher levels of adequacy based on their proximity to each of the four indicators of slum conditions.
These four kernel density maps were generated showing access to durable housing, water, sanitation, and amenities across Rajarghat. While these maps each show the varying levels of access individually, by combining them into one map my research examines and displays access to all of these indicators in one place for the entire slum (Figure 41) and for the survey area only (Figure 42). To create these maps, I used the ArcMap Weighted Sum tool to generate a map that was the sum of all four kernel density raster maps together. Since each of the indicators are of the same importance, the weights for each map were all set to one. The final maps then are Kernel Density maps that show the combined access to all four indicators. Higher values indicate closer access to more indicators and would be considered to be more adequate areas of Rajarghat.
Figure 41. All four kernel density maps combined.

Figure 42. Combined kernel density map (survey area only).
The second application of the index of adequacy was in creating a chart of slum adequacy conditions. Of the houses surveyed in my research, 17 of 82 would be classified as Level 1 adequacy. This means they were constructed of both non-permanent walls and roofs. This means that an estimated 22% of Rajarghat houses lack durable housing structure. Conversely, 78% of the homes would be classified as either Level 2 or 3 adequacy and would be considered to be of adequate housing structure. Per information from the Kolkata Municipal Corporation, the total population of the Rajarghat is 10,189, and the total number of households is 2,613, meaning there are approximately 3.9 people per household in Rajarghat. My previous analysis shows that 73% of Rajarghat is within 100ft of a water source and 76% of Rajarghat is within 100ft of a sanitation facility.

In summary, Table 4 shows indicator values usable for comparative purposes over time or involving other cases.

Table 4

*Index of Adequacy*

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of slum area within 100ft of water source</td>
<td>73%</td>
</tr>
<tr>
<td>Percent of slum area within 100ft of sanitation facility</td>
<td>76%</td>
</tr>
<tr>
<td>Percent of Level 2 or 3 adequate dwelling structures</td>
<td>78%</td>
</tr>
<tr>
<td>Number of people per household</td>
<td>3.9</td>
</tr>
</tbody>
</table>
My research set out to answer three research questions: What are the slum conditions in Rajarghat? Do the visual indicators of slum conditions exhibit any spatial pattern? And, how can the slum conditions be assessed based on an index of adequacy?

These questions can all be answered by my research and are all exemplified in the results section. Housing types are distributed somewhat randomly across the slum but with some clustering. Water taps and sanitation facilities are also distributed across the slum in all areas. As displayed in the maps that show the area within 100 feet of an amenity, even without a complete data set, it is obvious that these amenities are distributed in all areas of Rajarghat. Additional amenities such as locking toilet structures and satellite dishes were found in Rajarghat, and have patterns to their distribution.

The obvious pattern in these distributions is the preponderance of significant points in the northeast portion of the slum. HotSpot and Clustering statistics show a clear trend towards the northeast in regards to locking toilet structures, satellite dishes, and fully non-permanent houses. Maps showing the areas within 100 feet of a water tap or sanitation facility also show nearly complete coverage in the northeast part of the slum.

This clustering of amenities seems to indicate that the northeast portion of Rajarghat is more advantageous than other areas, or at least are home to residents who may be better off than the general population of the slum. Whereas the distribution of housing types (permanent/non-permanent/semi-permanent) throughout Rajarghat was generally random (with most houses being semi-permanent with permanent walls and non-permanent roofs) with a few clusters of certain housing types, the previously mentioned cluster of fully non-permanent structures in the northeast is of particular interest. At first glance this may seem contradictory to the earlier
postulation that this northeast corner was a more advantageous place to live. However further examination provides some explanation. Photos (Figure 43) and field notes show that one of the four non-permanent houses in the cluster area is home to residents established enough to have a satellite, and another appears to double as both a residence and a facility for rag picking.

Figure 43. Non-permanent home with a satellite dish and a home housing rag picking.

This could imply that these are also newer structures, built on the periphery of the slum where space existed and conditions were more favorable. This actually furthers the hypothesis that this is an advantageous area to reside in. It was most likely a concerted effort to put this rag picking center near an access road and some family or residents with enough money for a satellite dish either chose to move to, or declined to move away from, the area despite their non-permanent house and the presumed means to do so. It is also possible the due to the threat of eviction, some residents with more resources choose to invest in amenities like satellite dishes which can be moved in the case of eviction, rather than in a more permanent house which would be destroyed in an eviction situation.

The combined Kernel Density map(s) generated as part of the index of adequacy also help to paint a picture of slum conditions and the varying levels of adequacy across Rajarghat. It is clear that some portions of the slum are closer to more and better infrastructure and more
amenities. Some portions of Rajarghat are more adequate than others. Many of the areas that show higher levels of overall adequacy are older parts of the slum, such as the southeast portion, where residents have invested in improvements over time leading to better infrastructure, housing and access to amenities. On the other hand, newer parts of the slum can still be vulnerable. Areas with large amounts of non-permanents housing for example, would be much more likely to suffer damages and destruction in the case of a natural disaster.

The contributions of my research can be seen in conjunction with each of my research questions. Before this research, the slum conditions of Rajarghat had not been examined using the techniques that I have implemented. My research also detected spatial patterns in the distribution of visual indicators across Rajarghat. Finally, through my research I created and generated an index of adequacy for Rajarghat, the methodology for which can be duplicated and used to compare slums across Kolkata or anywhere.

In addition to answering my research questions, the results, findings and nature of my research also tie into several of the key schools of thought and bodies of literature regarding the slum phenomenon. Unskilled migrants who initially came to Kolkata to better their lives are forced into the slums on the outskirts of the city as part of the informal sector. Rajarghat is a prime example of this. Migration theory contends that migrants will move to a central area of commerce, to better their lives. Rajarghat is located in the commercial center of Kolkata, and its specific characteristics, particularly its rag picking based economy which caters to unskilled workers, make it an area that attracts and sustains a large population.

The work done by the informal sector in Rajarghat does have a role in how the city operates by contributing to the waste collection and sorting efforts on a local scale. Slums, and Rajarghat specifically, do benefit the city and provide it with resources that should be considered
when slum upgrading or removal policies are considered. The communal nature of the rag
picking work done in Rajarghat is also an example of social capital. By working together, the
slum dwellers convert their networking and social capital into financial capital (albeit at a low
level) and maintain a local economy.

Direct visual observations made during the primary data collection for my research did
not plainly show any slum dwellers that were lacking the basic needs of food, clothing, and
shelter. However, these observations coupled with further analysis show there is still a visible
delineation between slum dwellers whose main focus is meeting these needs and other residents
who are able to focus on “moving up the ladder,” whether that be by having savings, living in a
more durable house, or having amenities like a satellite dish or personal bathroom facility. These
observations reinforce the “bridgeheader” and “consolidator” ideas proposed by John Turner and
referenced here earlier. On a base level, all residents of Rajarghat appeared to be having their
basic needs met. The number of people who can afford things like that is a small percentage of
the population. These people, once meeting their basic needs can incrementally increase their
standing in life. It would be foolish to pay for TV when struggling to buy food. It is only after
basic needs are met, that people can begin to slowly enhance their life, moving up the ladder one
step at a time.

This incremental ascent can also be seen in where people choose to live. Once basic
needs are met, if a person or family has savings, they could construct a more durable house,
move to a part of the slum that is more desirable, or potentially be able to move away from the
slum altogether. This progression plays into the theories of bottom-up and self-help slum
development. If resources were allocated more efficiently, this progression could be kickstarted.
Instead of just providing an apartment building for slum dwellers to move into, resources
allocated to helping slum dwellers acquire better skills and thereby find better work, could help people to help themselves and potentially break the cycle of poverty.

A lack of water or sanitation facilities can have negative impacts on health and on quality of life for residents. With Rajarghat having significant number of both water taps and sanitation facilities, the negative effects of a lack of either are alleviated. Health concerns are at least somewhat addressed by the sanitation facilities, and the distribution of water taps around Rajarghat means that people are spending less time fetching water and have more time to devote to other things. While the source of some of the sanitation facilities and water taps may at times be up for debate, there is no doubt that at least some of them were placed in the slum by an outside group or entity. This is an example of a small change that can potentially expand to have a lasting and growing impact on the community. Children spending less time fetching water have more time for educational activities, and this could have a very positive impact on their lives.

While we know that some of the water taps and sanitation facilities were provided by government or outside entities like the KMC, we also know that some have been built or placed by the slum residents themselves. When examining the locations of water taps and toilet facilities recorded during this primary research and comparing that with the locations of water taps and toilet facilities provided by the KMC, it is evident that there are dozens of each that the government is not aware of, or at the very least, that were not built by the government. This difference in numbers and locations becomes even more pronounced when the fact that my research was not able to survey the entire slum. Had that been possible there would have been even more examples of water taps and toilets that are not provided by the government. The creation of these new, self-provided water taps and toilets is a prime example of self-organization amongst the residents of Rajarghat. By constructing their own facilities, the
residents can lessen the strain on the facilities that are provided for them. More facilities, simply means, better access and less time spent waiting in line. This again plays into the ideas of “bridgeheaders,” “consolidators,” “self-help” and moving up the ladder towards a better and more comfortable lifestyle. Once a family’s basic needs are met and met on a continuing basis, they will then start to incrementally improve their standing. A family with some extra money, after having basic needs met, could then afford piping and/or a plumber to run a water line and provide them with a tap at their home or at least closer by. These are taps that the government would likely not be aware of, and are an example of “self-help.” Additionally, since only people who were beyond the point of having basic needs met would be constructing new water taps or toilets for themselves, it is likely that areas with large numbers of taps and toilets would be more likely to be inhabited by people with more money. This creates a sort of cycle, people in a more advantageous area have more money and then build new amenities in that area. Those new amenities make that area even more advantageous to live in, and a cycle of improvement can continue. This can be seen in the southeastern portion of Rajarghat in the index of adequacy kernel density maps. The southeast portion has been built up over time as the slum has grown and is now more adequate than other areas.

Though Rajarghat is but one example of the worldwide slum phenomenon, by using it as a case study, my research begins to fill in the gaps of knowledge about slum conditions and infrastructure. By looking at visual indicators and analyzing their spatial distribution to study the slum’s infrastructure my research successfully answers the research questions herein. Clear patterns were apparent in the distribution of several key indicators, and geographic influences were discovered, cataloged and analyzed. Conclusions can also be drawn about the infrastructural makeup of Rajarghat that may be applicable to other slum areas. Consequently,
this research, or a variant of it, can be duplicated and used to examine and compare slum conditions in other areas.

Scope of Future Research

As discussed in the results section of my research, the main limitation was simply the inability to survey the entirety of Rajarghat, especially with regards to locating each water tap and toilet facility. With the manpower and time constraints facing the group, as much data as possible was acquired. This allows for substantial analysis; however, future research could benefit from, and be enhanced by, a more complete dataset. Future research could also benefit from speaking with slum residents to see if some of the patterns and statistics are congruous with anecdotal evidence from the slum residents. Geographic influences could also be examined in future research. The clear patterning that is evident in the northeast corner is most likely geographically influenced, and future research could examine that possibility.
References


Dash, Dipak Kumar (2013, August 28). By 2017, India's slum population will rise to 104 million The Times of India. Retrieved from timesofindia.indiatimes.com/


Okey, B., Ghosh, S., Tramontina, B., Keith, D., Murphy, D., Ortiz-Cortez, G., … Bera, S. (2016). *Exploration of Socio-economic and Environmental Conditions in Rajarghat Slum, Kolkata, India*. Unpublished manuscript


UN-Habitat Participatory Slum Upgrading Programme. (2016). *Slum Almanac 2015/2016*. Unon, Publishing Services Section, Nairobi


