Spatial modelling for understanding the correlation between school facilities and academic performance in the Philippines

Author:
Figueroa, Ligaya Leah

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Spatial Modelling for Understanding the Correlation between School Facilities and Academic Performance in the Philippines

Ligaya Leah Figueroa

A thesis in fulfilment of the requirements for the degree of Doctor of Philosophy

UNSW AUSTRALIA
School of Civil and Environmental Engineering
Faculty of Engineering

March 2016
Abstract 350 words maximum: (PLEASE TYPE)

School facilities serve as places of learning for young people and are proven to have significant effect on education outcomes especially for developing countries. Since substantial funding is required for the provision of suitable school facilities, local context and limited resources in developing countries necessitate the prioritization of school facilities. The main purpose of this study is to examine the spatial variation of school facilities and identify which feature has the largest impact on academic performance in selected localities. The Philippines is chosen as a case study due to the recent reform in its education system and consideration of its unique geographic characteristics. Acquired government-provided and open-source school facility data as of 2013 have revealed that only 38% of its public school buildings are in good condition.

This study employed statistical spatial analysis methods to understand the relationship between education, society and the environment. Regionalization and cluster analysis has revealed that school buildings in the capital are overcrowded but are in relatively better conditions than in the natural calamity-prone eastern seaboard region and in some southern provinces experiencing civil conflict. Global, local, and semi-parametric regression analyses indicate that the observed spatial variations in the provision of resources among the government schools are affecting academic performance. In the nation's capital, public elementary schools primarily serve the urban poor. An examination of education facilities in its largest city indicates that the provision of school health clinics is correlated with better education outcomes. All in all, schools in urbanized areas in the Philippines should focus on the provision of large schools with lower pupil-teacher ratios. The provision of better school facilities had the most positive effect on academic performance in sparsely populated rural areas where the communities still lack these basic services. As the identified facilities influencing academic achievement varied depending on the location's social and economic infrastructure, the provision of school facilities should be based on the unique needs of each community. Semi-parametric, geographically weighted regression modelling outperformed global and local modelling, and estimated up to 30% of the variation in education outcomes.
This thesis is dedicated to the land of my birth, a country blessed with many children. I hope that a better place will be provided for them – because the future is in their hands.
Acknowledgements

First and foremost, this endeavour was only made possible because of God, who gives us the victory through our Lord Jesus Christ (New American Standard Bible, 1 Cor. 15:57). He alone provides all our needs, and in everything we give Him thanks.

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This journey would not have been possible without my strong and supportive husband, Freddie. Your love and sacrifice for me and our beautiful children, Luisa, Leanne and Franxis, have made this experience more meaningful and inspirational. Thank you for going through this adventure with me. How wonderful indeed are the blessings God showered on us.

They say that it takes a village to raise a child. I have realized the truth in this proverb as this PhD meant that I had to uproot my young family to live with me in a foreign country. I would like to thank the families in our “village” that helped us “raise” our children during these four memorable years: the Fabian, Que, Quiwa, Ringor, and Urmeneta families, as well as friends we have known through La Perouse Public School and St. John’s Maroubra Anglican Church. Wimelda Fabian, my aunt who always remembers to pray for me. Zetty Hamid and Isabella Ke, my colleagues at UNSW who have made working at the office more enjoyable. Our irreplaceable families in the Philippines: my thoughtful father, Eugenio Lara and of course the Lara and Figueroa families who always manage to keep in touch and make us feel that we have not left home. Thank you for sharing memories that make us feel special and loved.
Abstract

School facilities serve as places of learning for young people and are proven to have significant effect on education outcomes especially for developing countries. Since substantial funding is required for the provision of suitable school facilities, local context and limited resources in developing countries necessitate the prioritization of school facilities. The main purpose of this study is to examine the spatial variation of school facilities and identify which feature has the largest impact on academic performance in selected localities. The Philippines is chosen as a case study due to the recent reform in its education system and consideration of its unique geographic characteristics. Acquired government-provided and open-source school facility data as of 2013 have revealed that only 38% of its public school buildings are in good condition.

This study employed statistical spatial analysis methods to understand the relationship between education, society and the environment. Regionalization and cluster analysis has revealed that school buildings in the capital are overcrowded but are in relatively better conditions than in the natural calamity-prone eastern seaboard region and in some southern provinces experiencing civil conflict. Global, local, and semi-parametric regression analyses indicate that the observed spatial variations in the provision of resources among the government schools are affecting academic performance. In the nation’s capital, public elementary schools primarily serve the urban poor. An examination of education facilities in its largest city indicates that the provision of school health clinics is correlated with better education outcomes. All in all, schools in urbanized areas in the Philippines should focus on the provision of large schools with lower pupil-teacher ratios. The provision of better school facilities had the most positive effect on academic performance in sparsely populated rural areas where the communities still lack these basic services. As the identified facilities influencing academic achievement varied depending on the location’s social and economic infrastructure, the provision of school facilities should be based on the unique needs of each community. Semi-parametric, geographically weighted regression modelling outperformed global and local modelling, and estimated up to 30% of the variation in education outcomes.
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<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AICc</td>
<td>Corrected Akaike Information Criterion</td>
</tr>
<tr>
<td>DBF</td>
<td>Database file</td>
</tr>
<tr>
<td>DepEd</td>
<td>Department of Education</td>
</tr>
<tr>
<td>FDR</td>
<td>False discovery rate</td>
</tr>
<tr>
<td>KDE</td>
<td>Kernel density estimation</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GWLR</td>
<td>Geographically Weighted Logistic Regression</td>
</tr>
<tr>
<td>GWR</td>
<td>Geographically Weighted Regression</td>
</tr>
<tr>
<td>LMI</td>
<td>Local Moran’s I</td>
</tr>
<tr>
<td>OLS</td>
<td>Ordinary Least Squares</td>
</tr>
<tr>
<td>S-GWR</td>
<td>Semiparametric Geographically Weighted Regression</td>
</tr>
<tr>
<td>SMU</td>
<td>School Mapping Unit</td>
</tr>
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Chapter 1
Introduction

Education is one of the substantial investments for most nations, and teachers form one of the biggest professional groups (Monteiro, 2014; Harris et al., 2013). School facilities serve as places of learning for young people and are proven to have significant effect on education outcomes especially in developing countries (Glewwe et al., 2011). In this thesis, the term school facilities refer to the following attributes of a school’s physical environment: the location, size, capacity, condition of each building; and the available utilities, services and equipment. In the context of developing countries, the provision of electricity and libraries to schools has shown to improve student learning (Hanushek, 1995; Bacolod and Tobias, 2006). The provision of well-maintained classrooms, suitable classroom furniture, tap water and toilets also positively correlated with better education outcomes (Urwick and Junaidu, 1991; Harbison and Hanushek, 1992; Glewwe and Jacoby, 1994). The crudity of school environments in developing countries is well known that even the provision of basic utilities (e.g., water, sanitation, electricity, and communication) is often sparse and minimal (Ghuman et al., 2006; Bacolod and Tobias, 2006; Glewwe et al., 2011). Higher returns on investments in education were found among poor country groups (Psacharopoulos and Patrinos, 2004). Some education resource studies have shown that there is a point of diminishing returns in the production function for school resources where the relationship between education resources and academic achievements is stronger in developing countries due to the lower level of resources per student in these areas (Boissiere, 2004).

While the effects of facilities are relatively small (and become insignificant) in comparison to family characteristics and socio-economic conditions in developed countries (Coleman et al., 1966; Ferguson, 1991; Hanushek and Luque, 2003), a larger impact of local community situations on the education outcomes of students was observed in the Philippines (Jimenez and Paqueo, 1996; Tan et al., 1997). Nebres (2009) documented how education reforms pertaining to the macro problems (e.g., social, political, and economic environments) of schools had greater impact on the improvement of academic outcomes in the Philippines, compared to educational
programs that targeted the micro problems (e.g., curriculum, teacher training, textbooks). A key challenge for the education sector of the Philippines is the lack of government funds. Management and maintenance of education facilities require significant investment, and thus the primary focus can be given to school building specifications that contribute to learning. This is especially pertinent to the current education environment of the Philippines due to the recent reform in their education system necessitating rapid school building expansions (Okabe, 2013; Shahani, 2015). Husén (1990) stated that school inputs (which have been represented in economic studies as school assets and learning processes) are influential to student achievement only up to a certain threshold of resources. Therefore given the large financial allocations necessary for the operation of the education sector and the relatively small impact of school facilities, at what point is it beneficial to pay attention for the improvement of school facilities in the context of the Philippines? At what point should efforts be directed to other objectives? This thesis intends to answer these questions by demonstrating that the effect of each aspect of the school facility to academic achievement might vary depending on the social infrastructure (e.g., income and occupation levels) and economic infrastructure (e.g., water supply, electricity, transportation and telecommunications networks, sanitation) of the locality.

Originally, the effect of education facilities on education outcomes has been investigated within educational planning and the economics of education. Educational planning is defined as “the application of rational, systematic analysis to the process of educational development with the aim of making education more effective and efficient in responding to the needs and goals of its students and society” (Coombs, 1970, p.14). Levin (1981) classified the approaches to education planning into four basic activities: logistics, technocratics, politics and research. Logistics do not involve a sophisticated technology or research but are necessary to ascertain the availability of resources that put political decisions into action. Education planning guidelines streamline the selection of school sites, construction specifications, purchase of materials, assessment of teacher requirements, and estimation of costs. Technocratic activities adopt scientific techniques and precise measurements to accomplish the purpose of education. Three traditional technical approaches: workforce forecasting, social demand projections and rate of return analysis (Blaug, 1967) fall in this category. Political activities pertain to the role of education planners in contributing to the political agenda such as perpetuating the role of education in solving social problems and overcoming
exploitation. Finally, research activities attempt to uncover the effect of education on the social, political, and economic state of the people. Levin (1981) argued that research activities should not merely employ a technocratic process but also uncover something fundamental about the connection between education and society.

In this thesis an educational planning research is conducted by employing a technocratic process to understand the relationship between education, society, and the environment. The first hypothesis is that the effect of elements of the school facility on academic achievement will vary depending on the social and economic infrastructure of the locality. This proposition is investigated through spatial analysis. The second hypothesis is that spatial analysis methods can aid in the development of a customized approach for the improvement of school facilities. Since local context and individual circumstances affect both education outcomes and school facilities, spatial analysis can provide valuable insights into the investigation on how school facilities affect education outcomes. However, relatively few studies have utilized this approach to identify school building specifications that contribute to learning, including Fotheringham et al. (2001), Cunha et al. (2009), Chamarbagwala (2009); Elias and Rey (2011) and Naidoo et al. (2013).

As will be discussed in Chapter 2, the unique geography of the Philippines imposes limitations on social cooperation and economic development within the nation. Therefore techniques that investigate spatial patterns in geographical space are useful in understanding school locations, physical facilities and academic performance, which has not been conducted for the Philippines before. By combining open online data with government-collected public school facility data, this research will also demonstrate that other spatial analysis methods (e.g., regionalization and cluster analysis through minimum spanning trees, semi-parametric geographically weighted regression) not employed in the previous education facility-focused spatial analysis literature also provide valuable insights into pattern recognition and spatial modelling due to the multifaceted nature of education data.

1.1 Research Objectives

This research proposes the development of a spatial model for education resource monitoring and evaluation in the Philippines. It will be conducted through spatial
analysis and regression modelling techniques implemented within a geographic information system (GIS).

The Philippine situation is selected as a case study for several reasons:
(1) It has recently (June 2012) implemented a 12-year pre-university education cycle – the old system had 10 years. This nationwide change resulted in a significant increase in school funds, workforces, and facilities.
(2) The various media reports pertaining to children with inaccessible schools as well as incidents of unsafe schools prompts a review of the country’s school locations and the current state of the facilities.
(3) The nation’s archipelagic form as well as the frequent occurrence of typhoons, floods, and earthquakes makes asset monitoring difficult and expensive.

This study aims to answer the following questions:
(1) What are the factors that have affected the allocation of education resources in the Philippines?
(2) How useful are spatial analysis techniques in the examination of school facilities?
(3) Which aspect of the education facility affects education outcomes and deserves further examination with a spatial model?
(4) How could the spatial model help stakeholders prioritize aspects of the school facility for improvement given the local context?
(5) How reliable, sensitive, valid and useful is the proposed spatial model in education resource monitoring and evaluation?

Following are the objectives of the proposed study:
(1) To review and understand the present condition and utilization of school facilities by studying and presenting relevant theories that affect educational planning as well as the historical events and policies that influences the government’s location of schools and allocation of education resources in the Philippines.
(2) To identify aspects of the school facility that affect education outcomes by exploring the government-provided school facility data and merging them with open data.
(3) To develop a spatial model that can estimate the effect of education resources on academic achievement using spatial analysis and regression modelling techniques implemented within a GIS.
(4) To provide evidence to policymakers on local conditions that affect school facilities and education outcomes using the spatial model.

(5) To test the usefulness of the spatial model by applying it in the context of districts with diverging conditions.

1.2 Contribution of the Study

This study adds to the body of knowledge by:

- Identifying spatial factors that affect school facilities and demonstrating how regionalization methods are able to analyse various indicators simultaneously and characterize spatial clusters.
- Demonstrating how school facilities are also affected by geography and the socioeconomic conditions of neighbouring provinces.
- Identifying aspects of the school facility that should be prioritized given the social and environmental conditions of a district.
- Examining how the physical urban environment affects academic achievement.

In terms of the Philippine context, the contribution of this study includes:

- The provision of a geographic profile of public school facilities in the country.
- Identification of the extent of provincial disparities in the provision of school facilities and distinguishing where and how education resources can be allocated in order to alleviate the disparities.
- The implementation of a spatial model that uses government-provided school facility data merged with open data to aid the investigation of community needs and identify aspects of the school facility that should be prioritized given the local conditions.
1.3 Thesis Structure

This thesis is divided into eight chapters. Chapter 1 provides an introduction of the research context and outlines the objectives and contributions of the thesis. Chapter 2 focuses on the topic of education resource planning as it provides a discussion of previous papers and examines the situation of the Philippines. Chapter 3 provides a summary of earlier papers that have focused on spatial analysis methods in the examination of education outcomes and shows an overview of the selected methods used in this research to develop the spatial model.

To achieve the research aims, it is first necessary to obtain a profile of public school facilities in the Philippines and investigate the available data. In the absence of publicly-accessible reports, Chapter 4 provides a summary by introducing the secondary data sources used in this research and examining the contents of the data file. Chapter 5 further investigates the spatial distribution of the school facilities and demonstrates the disparities across the country through local statistics and regionalization methods.

Based on the results of Chapters 4 and 5, a separate analysis of capital and regional schools is necessary in the spatial model due to the observed difference in the characteristics of these schools. Chapter 6 identifies the aspects of school facilities in the capital that affect education outcomes using geographically weighted regression modelling. Chapter 7 explores the counterpart context of schools in regional locations that are distant from the capital. Chapter 8 evaluates the utility of the GIS-based model for decentralized education resource monitoring and evaluation.
Chapter 2
The Equality of Education Opportunity in the Philippines

Education outcomes are strongly affected by family conditions and neighbourhood characteristics (Attar et al., 1994; Leventhal and Brooks-Gunn, 2000; Ainsworth, 2002; Reardon, 2011). Similarly, school facilities are affected by a complicated mixture of social, cultural, political, and economic factors within its internal and external environment (Withum III, 2006). According to the Coleman Report, school effects in the USA are very small in comparison to socio economic background and non-school factors – the key aspects influencing education outcomes (Coleman et al., 1966). Heyneman and Loxley (1983) took this idea further and stated that the school effect becomes stronger in poorer countries and less as a society becomes more industrialized. However, the best strategy for education resource allocation will vary even within countries based on the findings of Glewwe et al. (2011) therefore just an increase of funding will not solve the problem for poorer nations. Since local context matters and substantial funding is required for the provision of suitable school facilities, the low resource base of developing countries necessitates the examination of school features that affect education outcomes in each situation.

2.1 Theoretical Perspectives of Student Performance and School Facilities

In this section, papers that investigate the relationship between school facilities and student outcomes are reviewed. The framework of these quantitative studies is the education production function. Production functions are intended to measure efficiency in resource allocation. Cohn (1990) described education production inputs as school and non-school factors which can either be controllable or non-controllable. Glewwe and Kremer (2006) depicted the production function for learning as:
\[ A = a (S, Q, C, H, I) \]

where \( A \) is skills learned (achievement), \( S \) is years of schooling, \( Q \) is an array of school and teacher characteristics (inputs that raise school quality), \( C \) is an array of child characteristics (including “innate ability”), \( H \) is an array of household characteristics, and \( I \) is an array of school inputs under the control of parents, such as school attendance and purchase of schooling materials. Although the inefficient nature of schools\(^1\) raises the question of the appropriateness of this mathematical relation as a means to measure education outcomes (Levin et al., 1976), Hanushek (1986) claimed that the instrument simply serves as a simulation of reality as it describes how education resources (inputs) can be transformed into education outcomes (outputs).

School facilities have to be monitored not only to ensure compliance with the recommended standards but also to minimize disparities across the country and provide its citizens equal access to education. To measure the quality and effectiveness of school facilities, some studies utilized specific variables such as building age, building cost accrued over time, classroom temperature, noise, lighting, ventilation, school furniture, space, attractiveness, and maintenance (Cash, 1993; Earthman et al., 1995; Hines, 1996; Arsen and Davis, 2006; Uline and Tschannen-Moran, 2008; Marshall, 2009; Maxwell and Schechtman, 2012). However, some studies employed an aggregated “score” that accounted for more detailed building features which are used to evaluate school facilities (Buckley et al., 2004; Picus et al., 2005). Further discussion on school facility evaluation can be found in Beynon et al. (1997), Hawkins and Lilley (1998), and Ortiz (2002). These studies demonstrated the various physical, environmental, and financial conditions that have to be assessed and monitored in the evaluation of facility suitability.

Several studies confirmed that good school facilities improve the student experience, especially in the developing countries (Glewwe and Jacoby, 1994; Hanushek, 1995; Behrman, 1994; Tan et al., 1997; Ghuman et al., 2006; Bacolod and Tobias, 2006)). Glewwe et al. (2011) reviewed published school facility literature from 1995 to 2010 and found that fully equipped schools with well-maintained rooms, suitable classroom furniture, and a school library, has produced better education outcomes. In the context of developing countries such as the Philippines, Tan et al.

\(^{1}\) Refer to the cited paper for a discussion of the six qualities of schools that make them inefficient.
(1997) found that investments in workbooks and classroom furniture give the best pay-off in the Philippine basic education. The study of Ghuman et al. (2006) showed that schools with better facilities had higher enrolments. Even the provision of electricity in selected Philippine schools mattered more than class size or teacher trainings according to Bacolod and Tobias (2006).

In the theoretical model of physical facilities and student outcomes, Cash (1993) formalized that financial allocations for education, school leadership and maintenance personnel impact the quality of school buildings in Philadelphia, USA. In addition, Tan et al. (1997) demonstrated that community characteristics also affect school environments in their econometric model of student achievement in the Philippines. In this thesis, a model is developed from the perspective of geographic information analysis to illustrate how education outcomes are affected by spatial variations in school environments. It builds on the findings of Tan et al. (1997) as it identifies other locally specific factors that affect schools and further defines community characteristics as a set of geographic, social, and political conditions that are distinctive in the region. To understand the local context, the next section provides an overview of the state of education facilities and the unique geography of the Philippines.

### 2.2 Education Facilities of the Philippines

The Philippines implemented a nationwide reform in its education system in June 2012. The main change was an increase of the pre-university education cycle from 10 years to 12 years. This transformation demanded a significant investment in the education system’s human resources and facilities, which prompted the legislators to increase the education budget in 2014 to 4.3% of the country’s gross domestic product. It is well known that basic school facilities in the country have been inadequate and insufficient, with various media reports describing the dire situation at the start of every school year (Miralao, 2004). This inadequacy is further discussed in Chapter 4 of the thesis. To alleviate the situation, various Philippine-based non-government organizations (NGOs) such as Synergeia and Check My School have been working on

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2 Although this has been the highest allocation for education in the Philippines for more than 15 years, it still falls short of the UNESCO standard of 6%.
developing local leadership, instilling public transparency and accountability, and engaging with local communities to monitor and support their local schools (Robredo, 2008; Shkabatur, 2012). This insufficiency is a perennial national problem but is understudied due to the scarcity of publicly available data on education facilities. Only a few researchers have investigated the Philippine public school facilities on a national scale, including Alba (2010b) who utilized government-provided data to demonstrate congestion as well as underutilization of teachers, rooms, and seats in high schools across regions through computer programming models, and Lanzona (2012) who recounted the occurrence of poor quality and geographically unsafe classrooms in the country and claimed that poor politics of school principals is a key factor in these inadequate structures.

A survey of literature on the Philippine education facilities shows that a review of allocation policies and continued monitoring of resources has been often advised but was not conducted by the Philippines’ Department of Education (DepEd) (Tan et al., 1997; Human Development Network, 2000; Miralao, 2004; Alba, 2010a; Maligalig et al., 2010). During the American occupation (1898 – 1946), the Philippine public education was designed to be decentralized and financed by the local towns. However, it was later centralized due to the lack of local financial resources. The Monroe Survey in 1925 disapproved of the excessive centralized control of public education in the country as it led to less involvement from other sectors. Wernstedt and Spencer (1967) commented that although only the town centres have the higher grades of primary school, about 80% of barangays\(^3\) have schools that accommodate the younger children, which was the highest figure in the Orient outside Japan at the time. Aside from the American occupation, more than 300 years of Spanish rule was also instrumental in the widespread establishment of education institutions in the country. Eventually, the decentralization was restored in 2001 through the Principal-led School Building Program (Bautista et al., 2008). In this decentralized system, DepEd was responsible for the management of nearly 60,000 schools across the country (see Table 2-1). But the responsibility of financing and acquiring school sites in their territories was delegated to the municipalities and cities. Each school district has a local school board composed of teachers and parents who decide on matters relating to school funds and facilities.

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\(^3\) A barangay is the smallest administrative division, the local term for a village.
Table 2-1. Schools Managed by the Department of Education

<table>
<thead>
<tr>
<th></th>
<th>AY 2012-2013</th>
<th>Elementary</th>
<th>Secondary</th>
<th>Total</th>
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<td>7,748</td>
<td></td>
<td>46,407</td>
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<td>Private</td>
<td>7,745</td>
<td>5,130</td>
<td></td>
<td>12,875</td>
</tr>
<tr>
<td>Total</td>
<td>46,404</td>
<td>12,878</td>
<td></td>
<td>59,282</td>
</tr>
</tbody>
</table>

There is a variety of literature on education outcomes, inequalities, and shortages in the Philippines. But none reported the physical and geographical state of the country’s public school facilities. This thesis aims to fill this gap by combining open online data with government-collected public school facility data to provide an overview of the physical and geographical state of education facilities in the country.

2.3 Geography of the Philippines

Geography is an essential factor in the establishment and supervision of nearly 60,000 schools across over 7,000 islands in the Philippines which has been described by Wernstedt and Spencer (1967) to possess numerous, varied and uncommon characteristics. Uplands occur over approximately 65% of the country’s land area. As Ullman (1960) studied spheres of influence within the Philippines, he realized that difficult terrain (e.g., the geographic divisions from water bodies and mountains) has resulted in disconnected districts and hindered development for most regions. The naturally fragmented communities gave rise to more urban centres as predicted by models of urban location and distribution. (See Ullman (1941) for a discussion of the relationship between urban centres and its surrounding land.) This diverse geography has significantly contributed to the regionalism within the country, which is divided into 3 island groups: Luzon (the location of Manila, the capital), Visayas, and Mindanao (see Figure 2-1).

There is a lack of regional convergence in the nation due to the concentration of economic activities in the capital (Diokno, 2012). Industrial development is rapidly progressing in the provinces situated in the northern island of Luzon where the capital is located, and is very slow among the provinces in the southern island of Mindanao. Poor transportation networks further exacerbated the alienation of those areas that are distant from the urban centres (Human Development Network, 2013). The diverse geography of the country explains as much as 47% of the variation in provincial income poverty.
as well as a significant portion of the variance in health, education, and income variations (Human Development Network, 2013). This interplay between economic activities and education outcomes in some developing countries is also discussed by Hanushek and Woessmann (2007a).

The Education Policy and Data Center (2012), an international organization specializing on education policies, has reported moderate regional disparities in primary school attendance rates in the Philippines with the highest at 93% in the Ilocos Region (situated in the northern part of the country) and the lowest at 72% in the Autonomous Region of Muslim Mindanao (located in the southern part of the country). Similarly, the Human Development Network (2013), the World Bank’s arm for education, health, social protection and labour issues, reported that years of schooling in the northern regions of the Philippines has higher values (i.e., better outcomes) than in the centre or southern regions. Moreover, the report demonstrates spatial autocorrelation in mean years of schooling through global statistics such as Moran’s $I$. Spatial autocorrelation is the correlation in values of variables due to the proximity of their location, which is contrary to the assumption of independent observations in classical statistics (Griffith, 1987). Since geography has been consistently identified as a major factor in the country’s development (or lack thereof), it is only fitting to analyse the problem of education resource allocation in the Philippines from a geographical perspective.
Figure 2-1. Map of the Philippines showing regions and provinces. Region names are indicated in Appendix B.
Chapter 3
Spatial Analysis Methods

Spatial analysis is a set of techniques for investigating geographical incidents where the findings rest on the spatial arrangement of the events (Haining, 1994). In this approach, events that occur in geographical space are described, explored, understood, and predicted using an object’s attribute values and geographic location. This activity can also be regarded as quantitative geography where spatial data are analysed before mathematical models of spatial processes are developed with the intention of understanding processes that influence spatial patterns (Fotheringham et al., 2000). Some activities of spatial analysis fall within spatial econometrics where spatial interaction and spatial structure are estimated through regression analysis (Anselin, 2003).

Spatial models have been developed and applied in many different contexts. They range from spatial interaction or gravity models where analysis is performed top-down, to cellular automata or agent based models where the analysis is bottom-up (Goodchild and Haining, 2004). This thesis follows the statistical spatial analysis method as described by Anselin and Getis (2010): the first step is the selection of observational units and the transformation or cleaning of data in preparation for analysis. This is followed by an exploratory or descriptive stage where data patterns or relationships are detected. The final step is confirmatory or inferential where errors, outliers, and sensitivity are assessed prior to model estimation and hypothesis testing.

3.1 Literature on Spatial Analysis Applications and Education Outcomes

A strategy that is used to select the proper location of schools is school mapping - which refers to the process of educational micro-planning that enable the organization and fair distribution of quality education (Caillods, 1983). School mapping was considered inappropriate in the Philippine setting because more than 90% of public
schools are built on donated lots and zoning plans are changed to reflect the current scenarios\(^4\) (Kelly, 1998; Ballesteros, 2000). Furthermore, the government is forced to build schools on unsuitable sites (e.g., near geographically unsafe areas or facilities that are hazardous to children’s health) if there is sufficient population demand within the area (Lanzona, 2012).

After reviewing papers that have studied the effects of school resources on education outcomes, Glewwe et al. (2011) advised future studies to identify the best strategy for each situation because they have observed that successful education resource allocation strategies vary even within countries. Evolutionary economics and innovation systems\(^5\) have also shown that the relationship between higher education and economic development is affected by local capabilities and geographic context (Kruss et al., 2015). School spending also varied spatially even among similar schools in the USA depending on location. This was proven through geographically weighted regression by Slagle (2007). Studies investigating the local context can suggest specific types of school facilities that are understood in the context of the unique needs of each community. Then, such efforts would lead to the advancement of education and economic capabilities.

Geographically weighted regression (GWR) proposed by Brunsdon et al. (1996) as a method to explore spatial variation has been used in estimating the spatial variation of education outcomes (Fotheringham et al., 2001). It has become a popular tool for the examination of location data and has been utilized in various fields such as health, ecology, geography, housing, and regional science (Harris et al., 2010; Páez et al., 2011). In this study, it is utilized to identify the significant school facility features that are associated with the top performing schools.

Few studies have utilized spatial analysis methods to investigate how school facilities affect education outcomes. Cunha et al. (2009) applied global statistics, local statistics and a linear regression model to demonstrate that proximity to poor neighbourhoods result in lower education outcomes for students in the city of Campinas, Brazil. Chamarbagwala (2009) also employed global and local statistics but

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\(^5\) Processes and interactions between people, resources and other circumstances that transform ideas into products
added spatial lag and error models to prove that school attendance in India is affected by spatially correlated cultural norms. Elias and Rey (2011) employed the same methods as Chamarbagwala (2009) but added a spatial cross-regressive model to show clusters of high performing schools near the coast of Peru and low performing schools near the rainforest and highlands. Another approach for spatial analysis was developed by Fotheringham et al. (2001) as they employed global and local regression models to estimate the spatial variation of Mathematics scores in 3,687 Northern England primary schools. This technique was replicated by Naidoo et al. (2013) as they employed global statistics, local statistics, global regression models, and local regression models to prove clustering of education outcomes due to selected socio-economic factors in Cape Town’s 261 secondary schools.

3.2 Research Framework

The objectives of this research are accomplished through the utilization of GIS and spatial analysis techniques. Figure 3-1 is a visual representation of the methods employed in this thesis. Although spatial analysis has been performed in various studies involving school locations and the prediction of education outcomes as mentioned in the previous section, the contribution of this study is the utilization of this method to understand school locations, physical facilities and academic performance. Due to data limitations, spatial analysis has not been fully utilized before for the analysis of school facilities in the Philippines. Moreover, this study also demonstrates that several spatial analysis methods (e.g., regionalization and cluster analysis through minimum spanning trees, semi-parametric GWR) not employed in previous education-focused spatial analysis papers can aid in the understanding of patterns and spatial relationships that can be observed from education data.
Figure 3-1. Research method

Phase 1

Phase 1 of the research is an exploration of the entire school facility feature dataset, which involved necessary data cleaning and transformation activities. In spatial analysis, exploring data before any models are fitted or hypotheses formally tested enables the analyst to get a feel for the data: identify outliers, distribution patterns and groups. In this approach, the role of GIS is the integrator in the pre-modelling phase and an evaluation tool in the post modelling phase (Fotheringham et al., 2000). The results will serve as a guide in understanding the characteristics of the data set and in further data transformation and scope selection. It is necessary to report the results in Chapter 4 due to the unavailability of detailed information regarding the state and spatial distribution of public school facilities in the Philippines.

In Chapter 5, further data analysis is performed with the aim to determine the extent of provincial disparities in the provision of school facilities and investigate where and how education resources can be allocated in order to alleviate the disparities. Factors that affect school facilities are identified by analysing various indicators simultaneously.

Descriptive activities (Stage 2) are employed to detect data patterns and relationships on a national level. Univariate and multivariate analyses were applied to explore the data. In univariate analysis, the only possible explanation is the overall spatial trend across the locations (i.e., to be spatially autocorrelated). Global statistics was employed to establish spatial autocorrelation. Local Moran’s I (LMI) analysis was employed to investigate the spatial variation of the physical environment of public
elementary schools across the country. Local methods of analysis such as Local Moran’s $I$ are important for GIS because they produce values of a statistic for each location and these values can be displayed using the mapping capabilities of GIS. Larger bandwidths highlight regional patterns and smaller bandwidths emphasize local patterns. Density estimates generated in this fashion are preferable to those generated by aggregating data to a grid.

In multivariate analysis, additional explanation is available via other spatially autocorrelated attributes measured at each location. By observing more than one variable at a time, groups of provinces with similar conditions were identified through cluster analysis and regionalization techniques. Cluster analysis is a data mining procedure where computer algorithms are used to search for pattern and structure within the data so that objects can be grouped according to measured attributes. Cluster analysis is exploratory and does not label the groups but finds structure or natural groupings within the data (Jain, 2010). Regionalization is a classification procedure applied to spatial objects with an aerial representation, which groups them into homogenous contiguous regions (Assunção et al., 2006). This method is useful for recognizing spatial patterns in large data sets that are represented as areal units.

The grouping tool of ArcGIS version 10.2 was utilized to perform cluster analysis and regionalization. This tool is able to show how the spatial fabric of the data looks like by grouping features that are most alike and identifying statistically significant clusters (ESRI, 2013). It implements the regionalization method proposed by Assunção et al. (2006) which uses minimum spanning trees to represent the relationship between spatial objects and then employs a SKATER (Spatial ‘K’luster Analysis by Tree Edge Removal) algorithm to partition the graph into user-specified groups, thereby producing the connected clusters. In addition, the tool is able to help the user decide on the appropriate number of clusters to partition the data through the Caliński and Harabasz (1974) pseudo F-statistic – a dendrite method for cluster analysis which examines the behaviour of the variance ratio criterion. The results of Stage 2 are essential in order to understand how to proceed with the next step involving inferential activities (Stage 3).

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6 A dendrite method is the process of assigning a set of points to a connected graph that has no circuits, which is also called a tree. Florek et. al. (1951) and Gower and Ross (1969) discussed the process of looking for the shortest dendrite or the minimum spanning tree, which is the basis of the dendrite method proposed by Calinski and Harabasz (1974).

7 The variance ratio criterion is an informal indicator of the most suitable number of clusters based on the given points.
Phase 2

Based on the results of Phase 1, the need for separate analysis in the capital and provincial areas is recognized. In Chapter 6, the largest city within the capital is selected. The location of informal settlements is added as input because, as will be discussed in that chapter, most public elementary school pupils in the study area live within these disadvantaged communities. Hotspots of poverty were identified through the kernel density estimation (KDE)\(^8\) of informal settlement point locations. Geospatial data were combined with school facility data and informal settlement polygons to estimate the relationship between academic achievement and the physical urban environment.

Inferential activities are employed to gain an understanding of the factors affecting the spatial variation of academic achievement in the schools: First, the Pearson correlation was utilized to narrow down and identify candidate variables pertaining to school facility features which were significantly related to academic achievement. Next, a data mining tool was utilized to evaluate which is the best combination among the candidate variables in the aim to predict school performance. In this step, the exploratory regression tool of ArcGIS was utilized to employ global modelling through ordinary least squares (OLS) regression\(^9\) and identify properly specified models where all independent variables are statistically significant but not correlated with each other, while the residuals are normally distributed but not spatially clustered.

Finally, local modelling is employed. GWR is a local regression model that measures relationships around each data point. It produces localized parameter estimates and localized versions of all standard regression diagnostics. Estimates can be obtained for any location, not just the data points. Spatially adaptive weighting functions can be incorporated in GWR to maintain uniform sample sizes for each parameter estimate. Bandwidth selection is important because small values will only estimate the data point itself and large values will be similar to global regression results. Golden section search uses the cross validation approach to provide guidance on selecting an appropriate value of that parameter. GWR does not aim to predict but instead explores the spatial variation in the parameters (Fotheringham, 2009).

\(^8\) KDE as described by Silverman (1986) is a smoothing algorithm where inferences are made on the data based on a smoothing parameter or bandwidth.

\(^9\) OLS as a method to estimate relationships in spatial data through a linear regression model is briefly discussed and compared with GWR in Brunsdon et. al. (1996).
Nakaya et al. (2009) further developed semiparametric GWR as an extension of GWR where relationships can be modelled using fixed and spatially-varying variables in one equation. That is, it allows mixing of geographically varying and fixed coefficients in a generalized linear model. Semiparametric methods provide a compromise between a full parametric specification and a non-parametric approach where the parameters are completely determined by the data, with very little prior structure (Fotheringham, 2009). Since a variety of variables that can either be fixed or spatially varying (e.g., environmental and socio-economic conditions) affect academic performance, semiparametric GWR will be useful as it allows stationary and non-stationary variables to be combined. Spatial variation occurs when the process observed within the specified bandwidth changes systematically which can be a result of either a trend in data or a change in the variance (Getis, 1994). On the other hand, observed processes are classified as fixed when they remain unchanged despite a change in distance or location.

In Chapter 7, a provincial study area is selected based on the occurrence of top performing schools in the country. Regression modelling activities are again employed to gain an understanding of the school facilities that are correlated with the top performing schools. Unlike in Chapter 6, a logistic form of GWR is utilized due to the nature of the dependent variable utilized in this chapter.
Chapter 4
A Profile of Public School Facilities in the Philippines

A school facility database improves the use of resources through the provision of valuable and timely information for the administrators (Castaldi, 1987). In the case of Vietnam, it has also ensured priority interventions for poorer schools and helped monitor school performance on the district level (Attfield and Vu, 2013).

In this chapter, the GIS-based school profiling database of DepEd Philippines is introduced and inspected as the main data source. Exploratory data analysis is performed as a necessary step in order to understand the structure, extent, and quality of the second hand data. Numerically and graphically summarizing the data is a key initial step in modelling. Geographic data from open source websites were utilized to visualize the spatial distribution of the school facility features. In the absence of publicly-accessible data reports, unique characteristics of public school facilities in the country were discovered at this point. A profile of public school facilities in the Philippines is presented in this chapter as the first step in achieving the research aims – it is a synthesis of things that have not been put together before in the Philippines.

4.1 The GIS-based School Profiling Database

The School Mapping Unit (SMU) within the Physical Facilities and Schools Engineering Division (PFSED) of DepEd is tasked to address the issues of school mapping, school access, school capacity, building maintenance, and site selection (for proposed new school sites) of more than 46,000 public schools in the country. In 2006, the SMU created a GIS-based School Profiling Database which contains information on school identification (school ID, name, type, address, GPS coordinates), school access (road distance, road types, road conditions, access bridges, access vehicles), school facilities (toilets, lights, ventilation, classroom), school infrastructure (building ID, building conditions, building age, funding agencies, floor area, land area, parking area),
and calamity damages (year, type of calamity, extent of damage). The database has 14 tables as enumerated in Table 4-1. The records in the main table are linked to the sub tables via the School ID field in a one-to-many relationship. Among all the sub tables, the School Building Info (sub table 2) is most complete with 75.8% of schools reporting their status.

Table 4-1. Tables in the GIS-based School Profiling Database

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Total Records</th>
<th>Total (N)</th>
<th>Schools (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN TABLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School Profile</td>
<td>45,190</td>
<td>45,190</td>
<td>100%</td>
</tr>
<tr>
<td>SUB TABLES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Access Roads</td>
<td>137,914</td>
<td>10,527</td>
<td>23.3%</td>
</tr>
<tr>
<td>2 School Building Info</td>
<td>176,893</td>
<td>34,253</td>
<td>75.8%</td>
</tr>
<tr>
<td>3 School Building Use</td>
<td>177,060</td>
<td>29,946</td>
<td>66.3%</td>
</tr>
<tr>
<td>4 Other Details of School Building</td>
<td>31,312</td>
<td>31,269</td>
<td>69.2%</td>
</tr>
<tr>
<td>5 School Furniture</td>
<td>71,552</td>
<td>29,302</td>
<td>64.8%</td>
</tr>
<tr>
<td>6 Toilet Facilities</td>
<td>97,291</td>
<td>28,830</td>
<td>63.8%</td>
</tr>
<tr>
<td>7 Utilities</td>
<td>25,907</td>
<td>3,516</td>
<td>7.8%</td>
</tr>
<tr>
<td>8 School Site</td>
<td>2,037</td>
<td>1,011</td>
<td>2.2%</td>
</tr>
<tr>
<td>9 Remarks</td>
<td>31,311</td>
<td>31,269</td>
<td>69.2%</td>
</tr>
<tr>
<td>10 Natural Disasters</td>
<td>18,221</td>
<td>14,548</td>
<td>32.2%</td>
</tr>
<tr>
<td>11 Non-School Owned Facilities</td>
<td>1,786</td>
<td>1,477</td>
<td>3.3%</td>
</tr>
<tr>
<td>12 Community Involvement</td>
<td>102,436</td>
<td>30,436</td>
<td>67.3%</td>
</tr>
<tr>
<td>13 Proposed Site Condition</td>
<td>19,537</td>
<td>6,739</td>
<td>14.2%</td>
</tr>
</tbody>
</table>

The data were collected through a survey form that was distributed to all the public schools and filled out by the school principals. Closer inspection of the records shows that 39 provinces had a good response rate that was greater than 90%, 28 provinces had a response rate between 60% and 90%, and 8 provinces had a poor response rate that was below 60% (see Table 4-2). The most complete table has school facility data up to 75.8% of all schools. This survey response rate represents approximately 30,000 out of 45,000 schools across 75\textsuperscript{10} out of 81 provinces in the country.

\textsuperscript{10} Including the Dinagat Islands.
Table 4-2. Schools with building information data in the GIS-based School Profiling Survey as of July 2013

<table>
<thead>
<tr>
<th>Percentage of Schools</th>
<th>Number of Provinces</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;90%</td>
<td>39</td>
</tr>
<tr>
<td>60%-90%</td>
<td>28&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Below 60%</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>75</td>
</tr>
</tbody>
</table>

<sup>a</sup> The Dinagat Islands was merged to Surigao del Norte in the GIS-based School Profiling Survey

Municipal boundaries were downloaded from www.PhilGIS.org – a website that provides free Philippine geographic data for educational and non-profit use. The maps were merged with the school data in two phases. First, the region, province, and municipality fields between the School Profile table and the municipality shapefile’s database file (DBF) records were matched. This yielded an exact match for 31,583 out of 45,190 school records, no matches for 13,055 school records, and duplicate matches for 552 school records. Working with the maps proved difficult as there were a significant number of errors (at least 150 errors in the 1543 municipal polygons - around 10%) regarding incorrectly labelled (duplicates or missing) polygons when the map records were merged with the school data records. All the missing and duplicate records were corrected and accounted for by manually correcting errors in the province and municipality names in the shapefile’s DBF records.

4.2 Public School GPS Locations

The GIS-based school profiling database has 45,190 public schools (based on the School Profile table). School GPS locations were obtained by estimating the location of the school’s flagpole through desktop pinning via Google Earth<sup>11</sup>.

Not all schools had GPS locations in the government database. It was necessary for this research to incorporate school GPS locations from other open sources in order to complement and check the accuracy of the government-provided school infrastructure data. A comparison and summary of the assembled public school GPS locations is illustrated in Figure 4-1. Inspection of the 4 data sets reveals similarities between the

<sup>11</sup> Architect Felix Villanueva, head of the SMU at the time that access to the database was requested in 2013, has noted errors in this strategy as the pins will also move when Google Earth changes its imagery. Hence, an exact GPS location taken on site is still needed.
GIS-based School Profiling System and CheckMySchool.org data. The GeoCommons data are somehow different (with the public school locations and Mapa Mo Paaralan Mo GPS coordinates uploaded by just one author).

**Figure 4-1.** Comparison and Summary of the Assembled Public School GPS locations(* indicates records with School IDs)

**Check My School**

Check My School is a World Bank-supported project that uses the social media to raise awareness on school concerns that need government attention (such as textbook deliveries and dilapidated facilities). The GPS locations of the public schools surveyed by the Check My School staff are published in their website. Likewise, the SMU provides Check My School with the GPS locations available in the SMU database. At least 8,361 public schools in the Check My School data have GPS locations that exactly match the SMU’s GIS-based School Profiling System – proof that the two offices are indeed working together to achieve a complete database of public school GPS locations.
Not all the GPS coordinates from Check My School was used for the study as there were no school IDs given for the GPS coordinates in the National Capital Region. A string comparison of school names in the GIS-based School Profiling System with Check My School data only yielded a 33% match (345 out of 1,041 school IDs) with few mismatches in school IDs for schools that had similar names. Close inspection also revealed that the Check My School data had private schools and universities (in addition to the public schools) which were not used in this study.

**GeoCommons**

As of July 2013, the Philippine government has released 24,495 GPS coordinates of public school locations via GeoCommons. Comparison of the GPS coordinates with the GIS-based School Profiling System show a few mismatches\(^ {12} \) (340 GPS coordinates - less than 1%). Meanwhile, comparison of school data between GeoCommons and Check My School yielded matches in 8,035 school IDs and 2,113 GPS coordinates (see Table 4-3).

**Mapa Mo Paaralan Mo**

In addition to non-government initiatives, the DepEd also has an ongoing crowdsourcing project called Mapa Mo Paaralan Mo (meaning “map your school”) where the teachers and staff across the country can use Google Maps to plot government school locations. The data from this project is collated by DepEd staff and published through GeoCommons. The GPS locations gathered as of July 2013 were all of public secondary schools. Comparison of the Mapa Mo Paaralan Mo data with the GeoCommons data yielded mismatches (29 GPS coordinates - less than 1%). Comparison of the Mapa Mo Paaralan Mo data with the Check My School data yielded record matches for 12 GPS coordinates (within the 106 matching school IDs) (see Table 4-3).

| Table 4-3. Comparison of GPS values between the three supplementary data sets |
|---------------------------------|----------------|
| Same School IDs | Same GPS values |
| CMS vs Mapa | 106 | 12 |
| Mapa vs GeoCommons | 4,254 | 3,797 |
| GeoCommons vs CMS | 8,035 | 2,113 |

\(^{12}\) This gives the impression that the author of the GPS locations published through GeoCommons may be working with a slightly different set of data from the author of the GPS locations as given in the GIS-based School Profiling Database.
In this section the validity of the school IDs of the GIS-based School Profiling Database’s main table (School Profile table) is established and the authenticity of the school locations has been verified against other data sources. The contents of the 13 sub-tables are explored for the remainder of this chapter.

4.3 Access to Public Schools in the Philippines

The economics of education evaluates two conflicting factors when considering access to education: school quality and school quantity. In school quality, the provision of good quality schools is prioritized. In school quantity, the focus is on the provision of schools that are accessible to pupils. Both require education resources. Therefore a compromise between quality and quantity has to be recognized due to the limitations on financial allocations (Hanushek, 1995).

Similar to other countries, there is also disparity in education access between urban and rural children in the Philippines. Although previous research by the Education Policy and Data Center (2012) reported no significant difference in primary school attendance rates in urban (89%) and rural (86%) areas, disparity in primary school completion rates is as high as 96% in urban areas against 86% in the rural areas. The GIS-based school profiling database reveals that, on the average, there are less than 0.2 schools per km\(^2\) in rural areas\(^{13}\) and more than one school per km\(^2\) in urban areas. The proliferation of urban schools in the country is reinforced by Republic Act 7880 (Fair and Equitable Access to Education Act, also known as the Roxas Law) which aims to promote education access free from regional bias – but by emphasizing population and shortages, it gives preference to the urban areas (Lanzona, 2012). Therefore more education resources were given to urban areas while schools in far-flung rural areas remained distant and inaccessible for children. Unfortunately, addressing the needs of these remaining populations will be more costly (Bray, 2002).

In an effort to solve this inequality in education access, the government initiated a project in 2001 to build one primary school for every barangay\(^{14}\), regardless of the considerations for population. This project was successful in solving the school quantity problem but was unable to solve the school quality problem. In fact, there were so many

\(^{13}\) The DepEd only opens a school if there are enough students in the catchment area to populate the classes in each grade level

\(^{14}\) A barangay is the smallest administrative division, the local term for a village
schools built that the country had 3,600-3,800 undersubscribed public elementary schools in school year 2007-2008 (Alba, 2010b). The SMU also received reports of classrooms that remain underutilized and were instead used by the community as meeting places, not for the intended purpose of schools for children. Apparently, the parents did not utilize the nearby schools and preferred to send their children to the bigger (but farther) schools. This is consistent with the findings of Yamauchi and Liu (2012) that only 70% of children in the Philippines live within the town where their schools are located. Underutilization is not only confined to rural areas as education planning officers attest to the fact that even within the largest city of the country, the majority of parents send their children to the overcrowded schools even if there are smaller schools nearby. Perhaps the parents thought that bigger schools provide a better education experience. In any case, this scenario seems to support the findings of Filmer (2004) that increasing school availability does not considerably improve enrolments. In this debate between quantity and quality, Hanushek (1995) concluded that establishing more accessible schools of lower quality is not the pathway to fostering good quality schools and therefore establishing good quality schools in advance is a good strategy; Kremer (1995) agreed and recommended that school quantity is a lower priority until a “quality level” of one textbook for every two students is achieved. Hanushek and Woessmann (2007b) also observed that efforts to bring children to school will only have an effect on students who were not previously in school.

**Transportation Access**

In the quest to solve school accessibility, it is not enough to build the schools. The government and the community should also provide adequate transportation infrastructure that enables the children to travel to school. The National Building Code of the Philippines 2005 (Chapter 1, Section 105) states that the proper location of a school site should “satisfy the 2-3km maximum walking distance from students’ residence to school or the 30min maximum travel time for public conveyance from student’s residence to school.” Studies that analyse the proximity of schools to major roads (Amram et al., 2011), the mode of school access (Schlossberg et al., 2005), the factors that influence active commuting to school (Timperio et al., 2006), and the relationships between school district size and bus transportation costs (Hanley, 2007) prove that there is a close relationship between school location and transportation networks.
The SMU tried to determine each school’s accessibility by asking respondents to measure the road distance from the school to the municipal hall. In Figure 4-2, data from the GIS-based School Profiling System shows that although majority of the schools are 2-8kms away from the nearest municipal / city hall, few are still located more than 10kms away. This supports the findings of Bacolod and Ranjan (2008) that an estimated 30% of the nation’s primary school students live more than 5 km from an elementary school. Aside from increased distance, access to poor roads is also reported by a few schools located in the southern island group of Mindanao (see Figure 4-3). The influence of transportation infrastructure on student academic performance has been proven by Levy (2004) and Mu and Van de Walle (2007). Chapter 7 examines its effects in the case of the Philippines.

Using Quantum GIS, an intersection of the map of water bodies with the barangay boundaries reveals at least 3,000 barangays bisected by rivers in this archipelagic nation. Given the unique geography of the country, it is not surprising that more than 20% of public schools (10,527 schools) reported access through bridge crossings (see Figure 4-3). A case in point is barangay Nenita in Northern Samar on the country’s eastern seaboard. This far-flung town has only one school. When the river swells during the rainy season, children from the other side of town are unable to go across. Local strategies to overcome these situations include the provision of modules that the students can study at home (Francia, 2008).

**Figure 4-2.** Number of schools by proximity (road distance) to the town hall as reported by 10,539 government schools (22.7%) (Graph shows up to 30km distance only)
Figure 4-3. Map of school road conditions with points representing school locations, red and yellow point colours representing poorer road conditions and larger point sizes representing more bridges to cross.
### 4.4 School Facility Resources

The DepEd recognizes the importance of school facilities and implements a colour-coding scheme that reflects each demand level to make the information easier to understand. In their colour coding scheme, blue and green colours mean low needs while red and orange colours mean high needs. This representation is shown in all DepEd offices as well as MapCentral.ph, a local GIS company that hosts an online map of public schools with the aim of raising funds for each school (MapCentral, 2011). The monitored resources are teachers, classrooms, seats, and toilets.

**School Buildings**

The Philippines has a school building program that prioritizes the construction and maintenance of school facilities. In Figure 4-4, peaks in school building construction is evident every 10 years with the highest peak occurring in 1995. These building constructions were mostly funded by the government but some were sponsored by international agencies. Eliciting financial support from private organizations and individuals can affect education outcomes according to Jimenez and Paqueo (1996). They found that student achievement scores are higher in Philippine primary schools that depend on local community financing due to open scrutiny from the public. Private organization funding for Philippine public schools increased in 1990.

Public school requests for facilities are proposed through priority lists prepared by division offices, which are then collated and evaluated in the central office. Various factors are considered in the preparation of this list such as available construction space, the current state of rooms (i.e., good, old or dilapidated), and the allocation target for the district. A one storey building will be demolished if there is sufficient budget to construct a new building with more floors. Based on the GIS-based school profiling database, only 38% of school buildings are in good condition as of 2013. The lack of maintenance in the school buildings is evident in Figure A-3. Aggregating the data by municipality, the map in Figure 4-5 shows the municipalities with poorly maintained school buildings. The country should not be deterred by the funds required to repair these facilities as good quality school facilities can be achieved at a relatively low cost if local materials and techniques are used (Boissiere, 2004).
Figure 4-4. Yearly School Building Construction, Funding, and Present Condition as reported by 75.8% of public schools

However, the adequacy of school facilities is not the only factor that needs attention. Dangerous objects such as cliffs, ravines, and overgrown trees are frequently reported because the donated lots were not subjected to the proper procedure of selecting appropriate school sites (see Figure A-4). As will be discussed in Chapter 5, the inherent geography of the country requires the schools to conduct constant monitoring and maintenance procedures to ensure safety and reduce disparity.
Figure 4-5. Mean school building conditions aggregated by municipality
Classrooms

The GIS-based school profiling database reveals that a typical public school in the Philippines has six classrooms contained within four single-level buildings (see Figure A-5 to Figure A-7). In the provision of classrooms, the DepEd Education Facilities Manual specifies a ratio of 45 students per classroom (Department of Education, 2010). But Figure 4-6 indicates that this ratio is not attained in densely populated urban areas with as much as 50-100 children per classroom. In urban areas of the Philippines, it is a common strategy for overcrowded schools (whether government-provided or privately-owned) to implement double shifts as this allows them to maintain the recommended ratios of students to facilities. Double shifts reduce overcrowding and maximizes the use of school facilities as the school divides the students into groups and accommodates one group at a time for each school day (Bray, 2000). For example, one group of pupils attend school in the morning and a second group attend school in the afternoon. The DepEd division office in Quezon City assumes two shifts in the formula to determine a school’s required number of classrooms and they have observed that the classroom-deficient schools will usually lack other types of facilities as well. Although each school reports population regarding double shifts annually, the data are unfortunately not available for this study.

Seats

School furniture such as chairs and desks were also found deficient. For shared desks, tables and chairs, the recommended ratio of two students sharing a desk is assumed (i.e., the number of shared desks were multiplied by two). Large variations were found in the data which motivated the use of the median instead of the mean. In Figure 4-6 as many as 1.6 students per seat allocation was observed in some provinces. This confirms the scenario of squeezing together more than two children per desk or having more than one shift per school.

Sanitary Facilities

In the provision of sanitary facilities, the GIS-based school profiling database reveals that 81% of the public school toilets are shared (male and female) facilities.

---

15 Quezon City is the most highly-populated city in the Philippines.

16 Number of required classrooms = \( \frac{\text{enrollment}}{90} \) – available classrooms
except in the nation’s capital where 90% are separate toilets (see Figure A-8). For these basic utilities, the DepEd Education Facilities Manual requires one toilet seat for every 50 females (or two toilet seats for every 100 females), one toilet seat for every 100 males, and one detached urinal for every 50 males (Department of Education, 2010). When the data are aggregated by province and 33 students per shared toilet is assumed (three shared toilets per 100 students), less than 20% of the provinces can satisfy the government requirement (see Figure 4-6). But the state of sanitary facilities in the nation’s capital is appalling with more than 200 students per toilet. The manual also had recommendations regarding group hand washing facilities and drinking faucets but no data was available on this resource.

**Water Supply and Sewage Systems**

A literature review of sanitation in schools performed by Jasper et al. (2012) shows that increased access to these facilities increases school attendance and promote children’s health but effects on education outcomes have not been proven. In the case of the Philippines, it is worth noting that the students are not the only users of these facilities. There are also reports from rural schools that the local community uses the school toilets during weekends. Figure A-9 shows that the majority of public schools get their water from adjacent rivers (39%) and water wells (26%). The majority have septic tanks (56%) but still a remaining 9% cope with self-drain sewerage facilities (see Figure A-10).

**Lights and Ventilation**

Other school practicalities include the provision of lights and ventilation. Although there were no guidelines on the manual, the data indicate that the provision of ventilation closely followed the provision of classrooms. However, disparities between provinces were observed in the provision of lights (see Figure 4-6) with as much as 2-3 times more students sharing school lighting facilities in the southern islands of Mindanao than in Luzon - with the exception of the capital where an average of 150 students share in a light source.

---

\[
17 \text{ Average Toilets per Province } = \frac{\text{student enrollment}}{\text{female toilets} + \text{male toilets} + \text{shared toilets}}
\]
Electricity and Communication Utilities

Figure A-11 shows that 87% of public schools get electricity from local electric cooperatives (78%) and Meralco\textsuperscript{18} (9%). However, attention is needed for the 13% that do not have access to electricity as the research of Bacolod and Tobias (2006) has proven that this basic utility increases education outcomes for elementary school children in the Philippines. In terms of communication facilities, 92% of the schools have access to landlines and mobile phones but 8% are only accessible through shortwave radio communications (see Figure A-12). Chapter 7 further examines the effect of school utilities on education outcomes in rural areas of the Philippines.

\textsuperscript{18}Meralco is the largest electricity distribution utility in the Philippines.
Figure 4-6. Student ratios per school amenity (seats, ventilation, classroom, toilets, and lighting) per province.
4.5 School Damages from Natural Disasters

The Philippines has several volcanic arc systems and suffers about 19 tropical cyclones each year (Yumul Jr et al., 2008). It is listed in the Belgium-based Centre for Research on the Epidemiology of Disasters (CRED) as the country with the highest number of recorded disasters during the twentieth century (Bankoff, 2004). In fact, the Philippines is unseen under the high intensity and volume of storm paths in the global distribution of observed tropical cyclone tracks from 1985-2005 as rendered by Nilfanion (2006). Being located in the Pacific Ring of Fire, the country is regularly affected by earthquakes.

The year 2006 was a “meteorologically abnormal year” for the Philippines with flash floods, landslides, and super typhoons (Yumul Jr et al., 2008). Due to these unfortunate events, the frequent occurrence of natural disasters was added in the planning of Philippine schools through the construction of the DepEd Disaster Risk Reduction Manual in 2006. This manual is based on the Hyogo Framework for action, a 10-year plan to make the world safer from natural hazards (Department of Education, 2008). Since Philippine schools are converted to evacuation centres during natural disasters, the manual gives guidelines, protocols, case studies, and other information for school personnel. It was created in order to protect the lives of the school community members and ensure the safety of school sites.

Figure 4-7 show that 32% of the reported school disasters occurred in 2006 – the year when the GIS-based School Profiling Survey was conducted. Aggregating the data by municipality, the map on Figure 4-8 shows the general location of the schools damaged by calamities. It is common in the Philippines to see flourishing schools in the midst of low income villages. Some evacuees steal the electric fans or use the desks for firewood during times of calamities – making the maintenance of school property even more strenuous than it already is.

Disaggregating the school disaster reports reveals that 90% of the recorded calamities that damaged the schools are from hydrological and meteorological (i.e., water-related) natural disasters – with 75% of them from typhoons; whereas 6% of the disasters are from geophysical disasters (e.g., earthquakes, volcano, dry mass movements) (see Figure 4-7). This is synchronous with data summarized from 1900-
2012 by Guha-Sapir (2014) that identifies storms and floods as the most reported (58% and 25%, respectively) type of disaster in the Philippines – affecting 92% of all economic damages from natural disasters. In general, schools in the Philippines experience frequent flooding and make every effort to elevate school buildings when they are situated near creeks or other bodies of water. Even the useless, inaccessible donated lots have their value when the lot elevation protects the students from floods and makes it a suitable evacuation centre. Flooding also affects urban areas, and computer resources of public schools in Quezon City are placed on the top floors to eliminate the risk of water damage.

As stated in Section 3.1, the government builds schools where there is sufficient population demand, even on unsuitable sites (Lanzona, 2012). For example in Quezon City, there are 6 schools situated within a dumpsite that accommodates over 100,000 residents. Public schools are also built within well-established informal settler communities because the poor contribute to the elevated classroom ratios. But in some areas where the building and zoning laws cannot be bent, the government refuses to build schools to satisfy the needs of the community. For example, children living in informal settlements within nature reserves are forced to travel long distances – sometimes crossing a few rivers – just to get to school.

![Figure 4-7](image-url)  
*Figure 4-7.* Annual calamity damage reports from schools, disaggregated by type of calamity
Figure 4-8. Annual calamity damage reports by type per municipality as reported by 32% of schools
Schools in earthquake prone areas regularly conduct drills even if the buildings are constructed to follow seismic code regulations. School sites have to be monitored regularly because, in the past, they were not subjected to suitability requirements prior to building construction. For example in Quezon City, a donated school site was later identified to be 200 m away from the fault line and confirmed to be at risk of soil liquefaction. This prompted the local government to look for another location that can accommodate the school. But the most unfortunate geophysical disaster in the country was the landslide in 2006 that covered a school in Southern Leyte when classes were ongoing – resulting in the deaths of 246 children and seven teachers (Lanzona, 2012).

Since the government has proved inadequate in monitoring the voluminous and various needs of the people, private citizens should be empowered to make informed decisions. It is hoped that the introduction of the open data policy in the country can increase safety as school location data and geological analysis results can be shared not only for public viewing but also for individual reuse and processing (PCDSPO, 2014).

### 4.6 The Current Condition of Public School Facilities in the Philippines

In this chapter a report is given on the physical state and geographic distribution of Philippine public school facilities using a combination of government and open source public school facility data. Various errors and inconsistencies in the available data were documented in this procedure but analysis can be performed nonetheless.

As expected, school density per square kilometre is higher in urban locations than in rural areas. Most school sites are on donated lots and some are located within geographically unsafe areas or in close proximity to facilities that are hazardous to children’s health. The majority of the schools are within a road distance of 8km from the nearest municipal hall but a few are located more than 10 km away with some schools reporting poor road conditions and access through bridges. If the geography of the Philippines is considered, it seems that distance from the nation’s capital plays a major role to facility overlay as these poor infrastructure areas are mostly located in the southern island group of Mindanao.

A typical public school in the Philippines has six classrooms contained in four single-level buildings. In highly-populated urban areas, the schools cope by having two
or more shifts each school day in order to accommodate 50-100 children per classroom. Across the nation, more than one student occupies each seat allocation. Urban-rural disparity as well as regional disparity was also observed in the provision of school facilities with 2-3 times more students sharing school lighting facilities in the southern island of Mindanao than in the northern island of Luzon. Some schools (13%) have no electricity while 8% have no landline or mobile phone access. The GIS-based school profiling database also reveals that 81% of public school toilets are shared (male and female) facilities except in the nation’s capital where 90% are separate toilets. Only 14 out of 77 provinces satisfy the recommended student-toilet ratio with schools in the capital having more than 200 students per toilet. The majority of public schools get their water from adjacent rivers (39%) and water wells (26%). Almost all schools have some form of sewerage facility but still a remaining 9% cope with self-drain sewerage facilities. Government funding accounts for the majority of school building constructions and the largest construction activity occurred in 1995. The overcrowded facilities suffer from major maintenance needs and only 38% of school buildings are in good condition.

The nation experiences frequent natural disasters. Data in the GIS-based school profiling database indicate that 32% of the reported school disasters occurred in 2006 with floods and storms comprising 90% of the recorded disasters. The geographic location of schools that are prone to natural disasters were shown. These schools not only burden the country’s financial resources but also endanger the lives of children. This scenario is further investigated in the next chapter.

Drawing from the results of this exploration, further work can be done to find answers to the following questions: (1) Do poor health and sanitation facilities affect education outcomes? (2) Does poor transportation infrastructure affect education outcomes in the Philippines? These questions are addressed in Chapters 6 and 7 of the thesis.
Chapter 5
Spatial Analysis of the Disparities in Education Facilities

This chapter further explores the disparity in education facilities of the Philippines that was detected in the previous chapter. The main objective here is to determine the extent of provincial disparities in the provision of school facilities and investigate where and how education resources can be allocated in order to alleviate the disparities. GIS spatial analysis methods are utilized in order to demonstrate how school facilities are also affected by geography and the socioeconomic conditions of neighbouring provinces. This chapter begins with the presentation of the indicators for measuring school facilities and is followed by presentation of the GIS methods and results. It concludes with a discussion of the implications for government policies and school facilities in various regions of the country.

Analysis in this chapter will employ global statistics to establish spatial autocorrelation as well as local statistics to analyse the clusters. However, since our goal is to identify spatial clustering in the data, the regression models that were employed in other papers discussed in Section 3.1 as a method to predict variable relationships are not appropriate. Moreover, the techniques utilized in the previous studies only permitted the analysis and visualization of cluster characteristics of one variable at a time. Instead, this study employs regionalization methods that use minimum spanning trees in addition to global and local statistics to analyse the characteristics of the clusters. This method enables the analysis of multiple variables simultaneously while adjusting for their geographic location and proximity to each other. In doing so, essential evidence on the effect of geography on education facilities is presented. This chapter also demonstrates how regionalization methods are useful to analyse various indicators simultaneously and characterize spatial clusters that are difficult to be recognized through global and local statistics alone.
The study area is the whole Philippines except for one region\(^{19}\) where the school facility data are not available. The Philippines is an archipelagic state of 7,107 islands with a land area of 300,000 km\(^2\). It is jurisdictionally divided into 18\(^{20}\) regions, 81 provinces, 144 cities, and 1,490 municipalities. It has one of the highest population growth rates at 1.9% annually and has officially reached the 100 million mark in July 2014 (Clarisse and Obanil, 2014). Philippine maps with jurisdictional boundaries (municipal, provincial, regional) were downloaded from www.PhilGIS.org.

The main aim of this chapter is to address the issues that affect school building conditions as a case study of the Philippines because only a few studies have been conducted and therefore the understanding of the Philippines’ education environment is very limited. School building conditions refer to the overall state of the school building facilities: its structural state as well as its capacity compared with the student population that it serves. The government-provided school facility data that represent 75.8% of the Philippine public schools were investigated to extend the findings of Alba (2010b) and Lanzona (2012). By utilizing various GIS analysis tools on provincial level data, this research attempts to portray the state of education facilities in geographical form and identify provincial patterns.

The chapter is organized as follows: first, it examines the data and the methods applied to conduct the analysis; then it discusses the results by considering the disparities in education access, the physical state of school facilities, and the effects of calamities on school assets; finally, conclusion and further work is presented.

5.1 School Condition Indicators

Many of the variables considered in the evaluation of school facilities as mentioned in Section 2.1 are available in the GIS-based School Profiling Database. But in view of the fact that provincial representation is low in the database, only the variables with almost complete records (i.e. the variables responded by almost all schools) are utilized. The building condition values can be used to measure the quality of the school facilities

\(^{19}\) There was no school facility data available for the Autonomous Region of Muslim Mindanao (which is composed of 5 provinces) because it is not administered by the DepEd central office.

\(^{20}\) The Negros Island Region is the newest addition, being created last May 29, 2015 through Executive Order 183. Previously, the provinces in this region were part of the western and central Visayas regions, which is reflected in the maps and data used in this research.
while the ratios of students to classrooms, toilets, and seats can be used to estimate the size of the school facilities in comparison with the student population that it serves (see Table 5-1). Intuitively, low student-classroom ratios, low student-toilet ratios, and low student-seat ratios are expected for the students’ wellbeing. In addition to such school condition indicators, lower building condition scores are desirable as they indicate better buildings. Hence this study includes all of the above indicators.

Table 5-1. School representation for each indicator

<table>
<thead>
<tr>
<th>Variables</th>
<th>Schools (count)</th>
<th>Schools (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building quality</td>
<td>Building Condition</td>
<td>34,253</td>
</tr>
<tr>
<td>Building size</td>
<td>Pupil-to-Classroom Ratio</td>
<td>34,253</td>
</tr>
<tr>
<td></td>
<td>Pupil-to-Seat Ratio</td>
<td>29,302</td>
</tr>
<tr>
<td></td>
<td>Pupil-to-Toilet Ratio</td>
<td>28,830</td>
</tr>
</tbody>
</table>

One of the limitations in this study is the lack of data regarding “double shifts” for the student population. As mentioned in Section 4.4, information about school double shifts can determine the exact number of students using the school facility at any given time.

**Building Condition**

In the survey, the school administrator assessed each building in the school as: ‘good’, ‘needs repair’, and ‘dilapidated’. The data reveal that only 38% of the school buildings are in good condition. In this study, a numeric value is assigned to each building condition ($BC$) where lower $BC$ values indicate better school buildings, as illustrated in Equation (5-1).

$$BC = \begin{cases} 1, & \text{good} \\ 2, & \text{needs repair} \\ 3, & \text{dilapidated} \end{cases} \quad \text{Equation (5-1)}$$

A public school in the Philippines usually has 4 buildings. The mean value is obtained in order to calculate one $BC_i$ per school $i$. A province $p$’s building condition score $BC_p$ is calculated as the mean $BC_i$ among all schools within province $p$. A score of 1.5 (midpoint between “good” and “needs repair”) is proposed as acceptable for schools.
Pupil to Toilet Ratio

The number of toilets and urinals per school building is shown in the GIS-based School Profiling Database. The toilet users are teachers and students. For this study, only toilets that are being used by students are considered. The toilets are further classified as for male, female, or shared use.

The data indicate that 81% of the public school toilets are unisex facilities except for the country’s capital where 90% are separate toilets. With overall student enrolment data at hand, all male, female, and unisex toilets are combined to compute a pupil-to-toilet ratio (PTR) per school as illustrated in Equation (5-2).

\[
PTR_i = \frac{e_i}{(m_i+f_i+u_i)}
\]

Equation (5-2)

where, for each school \( i \), \( PTR_i \) is the pupil-to-toilet ratio, \( e_i \) is the overall student enrolment, \( m_i \) is the total number of male toilets, \( f_i \) is the total number of female toilets, and \( u_i \) is the total number of unisex toilets. Due to large variations in the toilet data, the median (instead of the mean) pupil-to-toilet ratio \( PTR_i \) among all schools within province \( p \) is utilized to calculate a \( PTR_p \) for each province.

In the provision of sanitary facilities, the Philippines’ Department of Education (2010) requires one toilet seat for every 50 females and one toilet seat for every 100 males. This standard varies for each country but the international standard is 25:1 for females and 30:1 for males (see Table 5-2 for a comparison).

**Table 5-2.** Pupil-to-toilet ratios for primary and secondary school toilet facilities in selected countries

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>International</th>
<th>Australia&lt;sup&gt;b&lt;/sup&gt;</th>
<th>UK&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong> ( t_m )</td>
<td>100:1</td>
<td>30:1</td>
<td>50:1</td>
</tr>
<tr>
<td><strong>Female</strong> ( t_f )</td>
<td>50:1</td>
<td>25:1</td>
<td>17:1</td>
</tr>
<tr>
<td><strong>Unisex</strong> ( t_u )</td>
<td>33:1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a</sup> Proposed, see Equation 5-3

<sup>b</sup> Per 100 facility users. (The recommended ratios increase with the number of facility users.)

<sup>c</sup> For pupils over 10 years of age.

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<sup>21</sup> Sources

US: 2012 Minimum plumbing fixture requirements for school buildings in Kentucky, USA.

AU: 2008 Toilet Amenities for Schools by the Department for Education and Children’s Services, South Australia.

In the absence of recommendations regarding unisex toilets that are prevalent in the Philippines, we propose a recommended pupil-to-toilet ratio \((t_u)\) for the country as Equation (5-3).

\[
t_u(x) = t_m(x) + t_f(x)
\]  \hspace{1cm} \text{Equation (5-3)}

where \(t_u\) is the recommended number of unisex toilet provisions for \(x\) pupils, \(t_m\) is the recommended number of male toilet provisions for \(x\) pupils, and \(t_f\) is the recommended number of female toilet provisions for \(x\) pupils. After substituting the number of recommended toilets for the Philippines, Equation (5-3) results in \(t_u = 3\) for \(x = 100\) which is approximately 33 pupils for each unisex toilet. Individual inspection of each province reveals that only 7 out of 75 provinces satisfy the proposed \(t_u\) in the Philippines (see Figure 5-1).

**Figure 5-1.** Ratio of pupils to classrooms and toilets in public schools of the Philippines

### Pupil to Classroom Ratio

The formula to compute the pupil-to-classroom ratio \((PCR)\) is illustrated in Equation (5-4).
where, for each school $i$, $PCR_i$ is the pupil-to-classroom ratio, $e_i$ is the overall student enrolment, and $c_i$ is the total number of classrooms. A province $p$’s $PCR_p$ is calculated as the mean $PCR_i$ among all schools within province $p$.

Ideally, classroom area should be used in the computation of the $PCR_i$. However, we use the total number of classrooms instead, because of unavailability of classroom area data. Whether a classroom can accommodate 30 or 60 students, it is still evaluated against the DepEd’s recommended PCR of 45. Individual inspection of $PCR_p$ reveals that 50 out of 75 provinces satisfy the recommended $PCR$ (see Figure 5-1). If double shifts in the severely overcrowded areas are considered, $PCR_p$ will be generally acceptable for all the provinces. Figure 5-1 shows that only one province (Batangas) has the right balance of classroom and toilet facilities to its student population. The other provinces had either too many or too few students for its current facilities. Hence, similar to a study by Alba (2010b) on public school congestion in 2007, the GIS-based School Profiling Database also reveals congestion in most provinces and underutilization of resources in a few provinces.

### Pupil to Seat Ratio

In the GIS-based School Profiling Database, there are three types of classroom furniture: table and chair sets, armchairs, and desks. In this study, it is assumed that only one student would sit in an armchair and two students are assigned to a desk. It is also assumed that two students sit in a table and chair set, but in reality three or four students would be squeezed in depending on class size. The pupil-to-seat ratio ($PSR$) is calculated as Equation (5-5).

$$PSR_i = \frac{e_i}{a_i + 2(t_i + d_i)}$$  \hspace{1cm} \text{Equation (5-5)}$

where, for each school $i$, $PSR_i$ is the pupil-to-seat ratio, $e_i$ is the overall student enrolment, $a_i$ is the total number of armchairs, $t_i$ is the total number of table and chair sets, and $d_i$ is the total number of desks. Due to large variations in the classroom furniture data, the median $PSR_i$ among all schools within province $p$ is used to calculate the $PSR_p$. 

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5.2 Global and Local Statistics

A distance that reflects the intensity of clustering in the school facility variables was selected by examining the distances between provinces and computing for Moran’s I at increasing distances. Since the z-scores of Moran’s I reveals the intensity of clustering, the distances with significant peaks in the z-scores are selected. Figure 5-2 indicates that clusters are best observed at the distance of 225 km for building conditions and pupil-to-classroom ratios while 250 km is best for pupil-to-seat ratios. Clusters in pupil-to-toilet ratios were best observed at a distance of 375 km. The westernmost province of Palawan had no neighbours within 375 km while the northernmost province of Batanes had no neighbours within 250 km. This is acceptable since the two remote provinces may be more related to the capital than the nearest provinces due to direct transportation routes which may be a better means of representing the adjacency between provinces but were unfortunately not available for analysis.

![Spatial Autocorrelation by Distance](image)

**Figure 5-2.** Computed z-scores of Moran’s I for each school facility variable at increasing distances between provinces (building conditions \(BC_p\), pupil-to-classroom ratios \(PCR_p\), pupil-to-seat ratios \(PSR_p\) and pupil-to-toilet ratios \(PTR_p\)).
Table 5-3 shows the results of computing Moran’s $I$ and indicates that the quality and the size of the school facilities (as expressed in $BCp$, $PCRp$, $PSRp$, and $PTRp$) signify a statistically significant clustered pattern and strongly influence neighbouring provinces in the entire data. Although the Moran’s $I$ for the $PTRp$ is not as strong as the other variables.

**Table 5-3.** Moran’s $I$ for each indicator

<table>
<thead>
<tr>
<th>Variable</th>
<th>Distance (km)</th>
<th>Moran’s $I$</th>
<th>Variance</th>
<th>z-score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PCRp$</td>
<td>225</td>
<td>0.33</td>
<td>0.0019</td>
<td>7.8</td>
<td>0.00</td>
</tr>
<tr>
<td>$BCp$</td>
<td>225</td>
<td>0.24</td>
<td>0.0020</td>
<td>5.7</td>
<td>0.00</td>
</tr>
<tr>
<td>$PSRp$</td>
<td>250</td>
<td>0.18</td>
<td>0.0017</td>
<td>4.6</td>
<td>0.00</td>
</tr>
<tr>
<td>$PTRp$</td>
<td>375</td>
<td>0.07</td>
<td>0.0009</td>
<td>3.0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*The expected value for the Moran’s $I$ statistic is $E(I) = \frac{-1}{n-1} = -0.013$ (n = 75)*

Statistically significant spatial clusters were identified by using the optimal distances in Table 5-3. FDR correction was employed to account for multiple testing and overlapping subsamples. The hotspots in Figure 5-3 and the clusters in Figure 5-4 indicate that northern provinces have the best $PCRp$ and $PSRp$ while the southern provinces had the worst $PCRp$ and $PSRp$. The country’s capital and its surrounding provinces had the best $BCp$ but were the most overcrowded with the worst $PCRp$. One province adjacent to the country’s capital (i.e., Rizal) had the worst $PTRp$ as indicated in Figure 5-4d while another province (i.e., Batangas) was identified as a High-Low outlier with poor buildings surrounded by provinces with relatively good buildings in Figure 5-4a. The eastern provinces had the worst $BCp$ and $PSRp$ with one province (i.e., Marinduque) identified as a Low-High outlier with good $PCRp$ while surrounded by provinces with overcrowded classrooms.
Figure 5-3. Map of hotspots for: (a) building conditions ($BC_p$). (b) pupil-to-classroom ratios ($PCR_p$). (c) pupil-to-seat ratios ($PSR_p$). (d) pupil-to-toilet ratios ($PTR_p$).

Figure 5-4. Map of clusters and outliers for: (a) building conditions ($BC_p$). (b) pupil-to-classroom ratios ($PCR_p$). (c) pupil-to-seat ratios ($PSR_p$). (d) pupil-to-toilet ratios ($PTR_p$).
5.3 Regionalization

Without Spatial Constraints

To determine the effect of geography, the data were first examined based on school facility data alone and without any consideration for location. The k-means algorithm calculated that the data should be partitioned in two groups to minimize the differences among the features in a group. It classified 53 provinces into Group X (blue) while the remaining 22 provinces into Group Y (red) as illustrated in Figure 5-5. Although geographic location is not considered, the map indicates that the provinces in each group are still predominantly close to each other. The grouping analysis tool of ArcGIS as shown in Figure 5-5 generates a map and parallel box plot of the results.

![Figure 5-5. Map and parallel box plot for grouping analysis without spatial constraints](image)

In Table 5-4 it can be seen that Group X is a group of the provinces with better facilities as its mean $PTR_p$, $PSR_p$, $PCR_p$, and $BC_p$ values were closer to the recommended standard ratios. On the other hand, Group Y is a group of the provinces with poor facilities. Its $PSR_p$ and $BC_p$ values are inferior (i.e., higher) and its $PTR_p$ and $PCR_p$ values are superior (i.e., lower).

---

22 The k-means algorithm evaluates the characteristics of a data and partitions it into clusters without imposing a hierarchical structure. A review of this widely-used data clustering algorithm is presented by Jain (2010).
PCR\textsubscript{p} values are almost twice that of Group X. Table 5-4 also indicates that PTR\textsubscript{p} is a more effective predictor of clustering (i.e., highest R\textsuperscript{2}) when the provinces are grouped in two clusters without considering location while BC\textsubscript{p} varies little throughout the country and are the least likely to predict clustering (i.e., lowest R\textsuperscript{2}).

**Table 5-4.** Group-wise summary of regionalization without spatial constraints

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PTR\textsubscript{p} R\textsuperscript{2} = 0.49</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp X</td>
<td>45.4</td>
<td>8.9</td>
<td>26.5</td>
<td>65</td>
<td>25%</td>
</tr>
<tr>
<td>Grp Y</td>
<td>81.2</td>
<td>27.1</td>
<td>43.0</td>
<td>176</td>
<td>88%</td>
</tr>
<tr>
<td>All</td>
<td>55.9</td>
<td>23.1</td>
<td>26.5</td>
<td>176</td>
<td>100%</td>
</tr>
<tr>
<td><strong>PSR\textsubscript{p} R\textsuperscript{2} = 0.41</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp X</td>
<td>1.02</td>
<td>0.14</td>
<td>0.64</td>
<td>1.25</td>
<td>58%</td>
</tr>
<tr>
<td>Grp Y</td>
<td>1.30</td>
<td>0.18</td>
<td>0.97</td>
<td>1.69</td>
<td>68%</td>
</tr>
<tr>
<td>All</td>
<td>1.1</td>
<td>0.20</td>
<td>0.64</td>
<td>1.69</td>
<td>100%</td>
</tr>
<tr>
<td><strong>PCR\textsubscript{p} R\textsuperscript{2} = 0.34</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp X</td>
<td>35.9</td>
<td>9.7</td>
<td>9.6</td>
<td>57.8</td>
<td>59%</td>
</tr>
<tr>
<td>Grp Y</td>
<td>52.2</td>
<td>11.8</td>
<td>34.5</td>
<td>90.8</td>
<td>69%</td>
</tr>
<tr>
<td>All</td>
<td>40.7</td>
<td>12.8</td>
<td>9.6</td>
<td>90.8</td>
<td>100%</td>
</tr>
<tr>
<td><strong>BC\textsubscript{p} R\textsuperscript{2} = 0.09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp X</td>
<td>1.66</td>
<td>0.08</td>
<td>1.45</td>
<td>1.81</td>
<td>85%</td>
</tr>
<tr>
<td>Grp Y</td>
<td>1.72</td>
<td>0.10</td>
<td>1.46</td>
<td>1.88</td>
<td>97%</td>
</tr>
<tr>
<td>All</td>
<td>1.67</td>
<td>0.09</td>
<td>1.45</td>
<td>1.88</td>
<td>100%</td>
</tr>
</tbody>
</table>

The R\textsuperscript{2} denotes the effectiveness of the variable in classifying the provinces into groups.

**Utilizing a Spatial Weights Matrix**

Examining the spatial relationships between provinces through contiguity is not appropriate due to the archipelagic geography of the Philippines. Some provinces are adjacent to each other while some are separated by the sea. As mentioned in Section 5.2, transportation networks can provide a more accurate representation of the spatial relationships between the provinces but it was not available for analysis. A spatial weighting matrix that designates provinces within a threshold distance as related to each other was utilized. Figure 5-2 indicates that clusters are best observed starting at the distance of 200 km. The Calinski-Harabasz pseudo F-statistic indicates that the data are best grouped in five clusters. The SKATER algorithm classifies two provinces closest to the country’s capital as Group A (blue), 18 northern provinces as Group B (red), seven provinces in the country’s eastern seaboard as Group C (green), six southern provinces
as Group D (yellow), and the remaining 42 provinces generally located throughout the country as Group E (purple). The locations of the groups are shown in Figure 5-6.

![Map and parallel box plot for grouping analysis with a spatial weights matrix](image)

*Figure 5-6. Map and parallel box plot for grouping analysis with a spatial weights matrix*

Comparison of the results shows that Group X represents an aggregation of Groups A, C, D, and some of E, while Group Y represents Group B and some of Group E. The corresponding parallel box plot in Figure 5-6 shows that Group A has the best facilities in terms of quality as it has the best $BC_p$, but is severely overcrowded with the worst $PTR_p$ and $PCR_p$. But if double shifts in the schools are considered and the Group A values are divided in half, it would have the same $PTR_p$ as Groups C and D, a comparable $PCR_p$ as Group E, and possibly have too many seats. This supports the findings of Alba (2010b) where the country’s capital (included in Group A) had the largest number of empty seats during school year 2007-2008. Group B has the best facilities that are acceptable in quality as well as in size with its average $BC_p$, $PSR_p$ and $PCR_p$. It also has the best $PTR_p$. Groups C and D generally have the worst $BC_p$ and critically high $PTR_p$. Group E spans across the whole country and portrays the “average” school facility in the Philippines. Disparity between groups of provinces is clearly observed where, for all variables, the worst-case scenario for the best group (Group B) is generally the best-case scenario for the poorest groups (Groups C and D).

Table 5-5 indicates that the $PTR_p$ is a more effective predictor of clustering (i.e., highest $R^2$) when the data are grouped in five clusters using a 200-km spatial weight
matrix (see Figure 5-6) while \( BC_p \) varies little throughout the country and are the least likely to predict clustering (i.e., lowest \( R^2 \)).

Table 5-5. Group-wise summary of regionalization using a spatial weights matrix

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp A</td>
<td>141.5</td>
<td>34.5</td>
<td>107</td>
<td>176</td>
<td>46%</td>
</tr>
<tr>
<td>Grp B</td>
<td>42.1</td>
<td>8.6</td>
<td>26.5</td>
<td>60</td>
<td>22%</td>
</tr>
<tr>
<td>Grp C</td>
<td>80.3</td>
<td>17.2</td>
<td>60.5</td>
<td>112.5</td>
<td>34%</td>
</tr>
<tr>
<td>Grp D</td>
<td>75.1</td>
<td>16.3</td>
<td>57.5</td>
<td>101</td>
<td>29%</td>
</tr>
<tr>
<td>Grp E</td>
<td>50.9</td>
<td>13.2</td>
<td>30</td>
<td>88</td>
<td>38%</td>
</tr>
<tr>
<td>All</td>
<td>55.9</td>
<td>23.1</td>
<td>26.5</td>
<td>176</td>
<td>100%</td>
</tr>
<tr>
<td>PCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp A</td>
<td>75.1</td>
<td>15.6</td>
<td>59.5</td>
<td>90.8</td>
<td>38%</td>
</tr>
<tr>
<td>Grp B</td>
<td>27.9</td>
<td>6.9</td>
<td>9.6</td>
<td>44.0</td>
<td>42%</td>
</tr>
<tr>
<td>Grp C</td>
<td>48.2</td>
<td>8.2</td>
<td>34.5</td>
<td>59.7</td>
<td>30%</td>
</tr>
<tr>
<td>Grp D</td>
<td>56.6</td>
<td>8.5</td>
<td>48.3</td>
<td>74</td>
<td>31%</td>
</tr>
<tr>
<td>Grp E</td>
<td>41.0</td>
<td>8.1</td>
<td>22.5</td>
<td>57.8</td>
<td>43%</td>
</tr>
<tr>
<td>All</td>
<td>40.7</td>
<td>12.8</td>
<td>9.6</td>
<td>90.8</td>
<td>100%</td>
</tr>
<tr>
<td>PSR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp A</td>
<td>1.45</td>
<td>0.20</td>
<td>1.25</td>
<td>1.65</td>
<td>38%</td>
</tr>
<tr>
<td>Grp B</td>
<td>0.95</td>
<td>0.16</td>
<td>0.64</td>
<td>1.15</td>
<td>48%</td>
</tr>
<tr>
<td>Grp C</td>
<td>1.34</td>
<td>0.18</td>
<td>1.07</td>
<td>1.69</td>
<td>59%</td>
</tr>
<tr>
<td>Grp D</td>
<td>1.31</td>
<td>0.16</td>
<td>1.14</td>
<td>1.65</td>
<td>48%</td>
</tr>
<tr>
<td>Grp E</td>
<td>1.08</td>
<td>0.13</td>
<td>0.66</td>
<td>1.42</td>
<td>71%</td>
</tr>
<tr>
<td>All</td>
<td>1.1</td>
<td>0.20</td>
<td>0.64</td>
<td>1.69</td>
<td>100%</td>
</tr>
<tr>
<td>BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grp A</td>
<td>1.49</td>
<td>0.03</td>
<td>1.46</td>
<td>1.53</td>
<td>15%</td>
</tr>
<tr>
<td>Grp B</td>
<td>1.66</td>
<td>0.06</td>
<td>1.49</td>
<td>1.77</td>
<td>64%</td>
</tr>
<tr>
<td>Grp C</td>
<td>1.80</td>
<td>0.03</td>
<td>1.75</td>
<td>1.87</td>
<td>27%</td>
</tr>
<tr>
<td>Grp D</td>
<td>1.75</td>
<td>0.06</td>
<td>1.66</td>
<td>1.88</td>
<td>51%</td>
</tr>
<tr>
<td>Grp E</td>
<td>1.66</td>
<td>0.08</td>
<td>1.45</td>
<td>1.81</td>
<td>85%</td>
</tr>
<tr>
<td>All</td>
<td>1.67</td>
<td>0.09</td>
<td>1.45</td>
<td>1.88</td>
<td>100%</td>
</tr>
</tbody>
</table>

The \( R^2 \) denotes the effectiveness of the variable in classifying the provinces into groups.

5.4 Resources Required to Minimize Disparity

Based on the mean values in Table 5-5, almost all provinces are unable to meet the recommended standards for school facilities. As discussed in Section 5.1 and summarized in Equation 5-7, the disparity will be reduced if each group aims to achieve these standards. But in reality the groups can only attain the recommended standards in relation to the resources that they already have. The increase or decrease in resources
that are needed to minimize provincial disparity is assessed and simulated in two steps. First, it is assessed how the provinces can achieve the proposed standards in relation to their current resources. Second, a scenario where the province resources are adjusted to achieve the proposed standards in relation to their groupings as indicated in Figure 5-7 is simulated.

The extent of increase or decrease of education resources in relation to the current resources in each group is calculated as Equation (5-6).

\[
Req_{r,g} = \frac{x_{r,g} - S_r}{x_{r,g}}
\]

Equation (5-6)

where \(Req_{r,g}\) is the required change in the resource \(r\) for the group \(g\), \(x_{r,g}\) is the mean value of the resource \(r\) for the group \(g\), and \(S_r\) is the recommended standard for the resource \(r\) summarized in Equation (5-7).

\[
S_r = \begin{cases} 
33, & PTR \\
45, & PCR \\
1, & PSR \\
1.5, & BC 
\end{cases}
\]

Equation (5-7)

The results presented in Table 5-6 indicate that there is an urgent need for an increase in sanitary facilities across all groups. School building conditions need to be improved for all except Group A, as the quality of their buildings is still acceptable even if 7% become dilapidated (currently evaluated as good but later becomes in need of repair). The classrooms and seats of Group E is sufficient while those of Groups A and B can be reallocated and those of Groups C and D should be increased.

Suppose that the values in Table 5-6 (i.e., \(Req_{r,g}\)) are satisfied, then the adjusted resource value for each province can be calculated as Equation (5-8).

\[
AdjReq_{r,p,g} = y_{r,p} \times \frac{S_r}{x_{r,g}}
\]

Equation (5-8)

where \(AdjReq_{r,p,g}\) is the adjusted value in the resource \(r\) for the province \(p\) in the group \(g\), \(y_{r,p}\) is the mean value of the resource \(r\) for the province \(p\), \(x_{r,g}\) is the mean value of the resource \(r\) for the group \(g\), and \(S_r\) is the recommended standard for the resource \(r\) that was summarized in Equation (5-7).
Table 5-6. Recommendations for identified groups of provinces (Req$_{r,g}$)

<table>
<thead>
<tr>
<th>Group g</th>
<th>Resource r</th>
<th>Increase in number of unisex toilets</th>
<th>Increase in number (or reallocation) of classrooms</th>
<th>Increase in number (or reallocation) of seats</th>
<th>Buildings that should be improved$^f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A (blue) (double shift)</td>
<td></td>
<td>77%</td>
<td>40%</td>
<td>29%</td>
<td>-7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(53%)</td>
<td>(-20%)</td>
<td>(-43%)</td>
<td></td>
</tr>
<tr>
<td>Group B (red)</td>
<td></td>
<td>21%</td>
<td>-67%</td>
<td>-11%</td>
<td>6%</td>
</tr>
<tr>
<td>Group C (green)</td>
<td></td>
<td>59%</td>
<td>6%</td>
<td>23%</td>
<td>17%</td>
</tr>
<tr>
<td>Group D (yellow)</td>
<td></td>
<td>27%</td>
<td>20%</td>
<td>23%</td>
<td>12%</td>
</tr>
<tr>
<td>Group E (purple)</td>
<td></td>
<td>34%</td>
<td>-10%</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>Overall (across the whole country)</td>
<td></td>
<td>40%</td>
<td>-13%</td>
<td>9%</td>
<td>6%</td>
</tr>
</tbody>
</table>

$^f$ Positive Values: number of buildings that should be in "GOOD" condition from initially being evaluated as "NEEDS REPAIR". Negative Values: number of buildings that are acceptable to be in NEED of REPAIR from initially being evaluated as "GOOD"

In Equation (5-8), a province is limited by its group as it attempts to attain the recommended standards. For example, Figure 5-6 indicates that the country’s capital belongs to Group A (blue). Equation (5-7) indicates that the recommended PTR standard ($S_{PTR}$) is 33. Table 5-6 indicates that the mean PTR in Group A ($x_{PTR,Group A}$) is 141.5. Substituting these values in Equation (8) yields $\frac{S_r}{x_{r,g}} = 0.23$ which is the rate of increase (or decrease) in toilet resources that will be applied for all provinces $p$ within Group A. Multiplying this rate with $y_{r,p}$ means that province $p$’s resource $r$ can only increase or decrease in proportion to the group rate. Hence, if province $p$’s resource $r$ is equal to its group $g$’s resource $r$, then it will meet the recommended standard for the resource $r$ accurately. Individual province data (see Appendix B) indicate that the mean PTR in the capital ($y_{PTR,Capital}$) is 176 which is not equal to the mean PTR in Group A. Hence the capital will miss the target standard PTR in proportion to its distance from the mean PTR of Group A. Based on this example, Equation (5-8) yields
\( AdjReq_{\text{toilets, Capital, Group A}} = 41 \). This means that based on the existing PTR in the country’s capital and in Group A, the capital will not reach the recommended standard PTR of 33 but will only achieve a PTR of 41.

Figure 5-7 displays the results as cluster analysis and regionalization was repeated using the computed \( AdjReq \) values. The Calinski-Harabasz pseudo F-statistic indicates that the simulated data are best grouped into just two clusters. The grouping analysis tool places nine provinces in Group F (blue). This group is perceived to have the best building conditions but the facilities are still somewhat overcrowded. The remaining 66 provinces are placed in Group G (red). Table 5-7 shows that this group has met the recommended standards for school facilities and represents the average school facilities in the country. The characteristics of both groups are shown in the corresponding parallel box plot in Figure 5-7. Overall variable statistics show that \( PCRp \) has now become the more effective predictors of clustering (i.e., highest \( R^2 \)).

**Figure 5-7.** Map and parallel box plot for grouping analysis on simulated data using a spatial weights matrix
Table 5-7. Group-wise summary of regionalization on simulated data using a spatial weights matrix

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCR</td>
<td>56.4</td>
<td>3.8</td>
<td>50.6</td>
<td>63.4</td>
<td>23%</td>
</tr>
<tr>
<td>Grp F</td>
<td>43.4</td>
<td>8.6</td>
<td>15.5</td>
<td>71.0</td>
<td>100%</td>
</tr>
<tr>
<td>All</td>
<td>45.0</td>
<td>9.2</td>
<td>15.5</td>
<td>71.0</td>
<td>100%</td>
</tr>
<tr>
<td>BC</td>
<td>1.43</td>
<td>0.07</td>
<td>1.31</td>
<td>1.53</td>
<td>69%</td>
</tr>
<tr>
<td>Grp F</td>
<td>1.50</td>
<td>0.06</td>
<td>1.35</td>
<td>1.63</td>
<td>87%</td>
</tr>
<tr>
<td>All</td>
<td>1.50</td>
<td>0.06</td>
<td>1.31</td>
<td>1.63</td>
<td>100%</td>
</tr>
<tr>
<td>PSR</td>
<td>1.08</td>
<td>0.11</td>
<td>0.87</td>
<td>1.22</td>
<td>50%</td>
</tr>
<tr>
<td>Grp F</td>
<td>0.98</td>
<td>0.13</td>
<td>0.61</td>
<td>1.31</td>
<td>100%</td>
</tr>
<tr>
<td>All</td>
<td>1.00</td>
<td>0.14</td>
<td>0.61</td>
<td>1.31</td>
<td>100%</td>
</tr>
<tr>
<td>PTR</td>
<td>35.4</td>
<td>2.9</td>
<td>32.0</td>
<td>41.0</td>
<td>23%</td>
</tr>
<tr>
<td>Grp F</td>
<td>32.6</td>
<td>8.3</td>
<td>19.4</td>
<td>57.0</td>
<td>100%</td>
</tr>
<tr>
<td>All</td>
<td>33.0</td>
<td>7.9</td>
<td>19.4</td>
<td>57.0</td>
<td>100%</td>
</tr>
</tbody>
</table>

The $R^2$ denotes the effectiveness of the variable in classifying the provinces into groups.

5.5 The Spatial Clustering of School Facility Conditions

Similar to the work by Alba (2010b), this study also found congestion and underutilization of facilities not only in public high schools but also in public elementary schools. The ratio of classrooms, toilets, and seats in clusters of the northern provinces are consistently in excess while the clusters of provinces around the highly-populated capital, the eastern seaboard, and the south are consistently deficient. The lack of public education facilities that serve the disproportionately large population in the capital cannot be solved even with a proposed reallocation of education resources in proportion to the current resources. Hence the current practice of double shifts will be hard to eradicate in the near future unless there is a drastic increase in funding for school facilities.

This study also found a clear need for more toilet facilities in public schools across the country. Even the group of provinces with good facilities i.e. Group B is unable to satisfy the study’s proposed standard for toilets ($t_u$) with its current mean $PTR_p$ of 42. But more disturbing is the fact that the group of provinces with severely overcrowded
facilities (i.e. Group A) has a mean $PTR_p$ of 141 (if double shift is considered, it is still a distressing 70 students per toilet). The quantity of needed toilets will be reduced if separate male and female toilet facilities are built instead of unisex toilets. In the aim of maximizing the limited resources and satisfying government standards, DepEd should discourage unisex toilets because they are meant to accommodate fewer pupils than separate toilets. As mentioned in Section 4.4, better access to school sanitation facilities increase school attendance and promote children’s health.

Individual inspection of each province reveals that only 15 out of 75 provinces have a mean $BC_p$ that is better than or equal to the proposed standard $BC_p$ of 1.5. Among the five groups, only the well-funded but severely overcrowded Group A located near the capital is able to meet this target. Although the building condition assessments utilized in the study may seem basic, Roberts (2009) showed that school facilities measured in terms of educational functions are correlated with learning outcomes.

Similar to Lanzona (2012), this study also found poor quality buildings in geographically vulnerable areas. In the country’s typhoon-prone eastern seaboard, school buildings are more dilapidated. Moreover, the deterioration of school buildings in provinces experiencing prolonged civil unrest is comparable to school buildings experiencing natural calamities.

The DepEd has fully documented how these community disruptions affect schools in a Disaster Risk Reduction Resource Manual that was disseminated with the aim of protecting the lives of the school community members and ensuring the safety of school sites during disasters (Department of Education, 2008). However, Lanzona (2012) recounted how numerous conflicts affecting the bureaucracy resulted in unsafe buildings even when geography was considered as the government is compelled to build schools even on unsuitable sites.

The planning of education facilities includes maintenance costs (Castaldi, 1987). Since public schools in the Philippines are converted to evacuation centres during times of disasters (whether the disruptions are caused by humans or the environment), the government should take into account the extent or rate of damage that are affecting facilities located in unsafe areas as opposed to facilities in other (safer) areas. The government agencies that manage activities related to these events should then provide the affected schools with more financial resources in order to build stronger buildings or conduct more frequent facility maintenance. After the disasters, affected buildings can
either be repaired or renovated. Stakeholders should decide on the appropriate action by considering the expected life of the building structure (Castaldi, 1987).

Tan et al. (1997) formalized the effect of community characteristics (which they were able to express as the region where the family resides) on class and school environments in their econometric model of student achievement by utilizing household and school survey data from the Philippines. Based on the spatial analysis of school building conditions in the Philippines, this study concludes that community characteristics, specifically the natural and social environments in the school’s provincial address, also affect the condition of education facilities. Therefore an enhancement to the model of Cash (1993) is proposed by adding the natural and social environments as a factor that affects the condition of education facilities aside from financial allocations and school leadership as indicated in Figure 5-8.

The present study illustrates that local statistics and regionalization using province-level data can reveal provincial clusters that non-spatial analysis models cannot. When the four indicators are analysed without considering location, the country is separated in just two clusters by the Calinski-Harabasz pseudo F-statistic which, interestingly, are still predominantly close to each other as evaluated by the k-means algorithm: Group X with good and average facilities (clustered in the northern and southern provinces and other parts of the country), and Group Y with poor facilities (clustered in the capital, the eastern seaboard, the south, and other parts of the country). However, when the four variables are evaluated in relation to their geographic location, the application of the Calinski-Harabasz pseudo F-statistic results in five clusters. Then, the SKATER algorithm determines which provinces satisfy the characteristics of the five clusters. The

Figure 5-8. Proposed enhancement to the Cash (1993) model of the relationship between school physical environment and student outcome variables
five clusters represent the provinces with good facilities (northern provinces), the provinces with severely overcrowded but good quality facilities (the capital and adjacent provinces), the provinces with average facilities (most of the provinces in the country), and finally, two disjoint clusters of provinces with poor facilities that shared comparable values (eastern seaboard and southern provinces). Further analysis using transportation networks may also be useful to find out how connected these provinces are.

The disparities between the groups are so great that, for all variables, the worst case scenario for the group of provinces with good facilities (northern regions) is generally the best case scenario for the two disjoint clusters of provinces with poor facilities (the eastern seaboard and southern regions). Education is highly valued by Filipinos and is generally perceived as a path to escape poverty. But if the state of school facilities differs such that the worst case for one group is the best case for another, then public education has failed to provide equal opportunities, which is its supposed goal (Tilak, 2002).

Results of this study should be considered in light of its limitations. First, Picus et al. (2005) pointed out the shortcomings of utilizing school facility data acquired through surveys and there is a possibility that the results may not be free from bias e.g. the school can misuse the surveys to request for facility improvements. However, the basic assumption is that the survey results are usable because of a high survey response rate. Second, the number of classrooms instead of classroom area or capacity was utilized. Hence a classroom is evaluated against the DepEd’s recommended PCR of 45 whether it can accommodate 30 or 60 students. Third, the lack of data regarding double shifts has altered the actual ratio of students to facilities in the urban areas. The computed ratios are more accurate in provinces with fewer urban areas and further from the actual scenarios in regions like the capital with larger urban areas. Fourth, the proliferation of unisex toilets in the country limited this study from computing the actual ratio of toilets to male and female pupils. Finally, large variations in school seats and toilet data prompted the use of median values instead of the mean.
Chapter 6
Modelling the Effect of Deprived Physical Urban Environments on Academic Performance in the Philippines

The results of Chapters 4 and 5 indicate that there is a great disparity between capital and provincial school facilities in the Philippines. Schools in the capital are overcrowded - though the facilities are in better conditions and are located in close proximity to each other. On the other hand, schools further from the capital have smaller student populations, fewer services, are located further from each other, and are more vulnerable to social and environmental disruptions. Ratios of toilets and classrooms to pupils as well as building conditions were identified as variables that can effectively differentiate school facilities in a cluster of provinces from the other regions on a national scale. Therefore these indicators served as a guide to investigate other variables which might be more relevant for smaller localities in the aim to identify how school facilities affect academic performance.

A better understanding of the unique characteristics and challenges faced by schools in each location can be achieved by developing separate models that allow distinct analysis for capital and provincial schools. The scenario for the capital is investigated in this chapter while the scenario for the provincial areas is studied in the next chapter. The significance of the spatial model should be investigated in the context of districts with differing conditions.

In the Philippines, two-income urban families usually send their children to private schools. Urban public elementary schools are perceived to be of lower quality and primarily cater to the very poor (Lam, 2005). In general, most of the students that attend Metropolitan Manila’s public elementary schools live in informal settlements or “slums” near their schools. The topic of informal settlements is discussed in the next section.
6.1 Deprived Physical Urban Environments

The United Nations Children's Fund (UNICEF) estimated that one fourth of the world's children are living in urban poverty (Bartlett, 2011). As one of the main purposes of public education is to provide equal opportunities regardless of social classes (Tilak, 2002) and reduce social disadvantages (Schütz et al., 2008; Machin, 2006), the establishment of suitable school facilities is the utmost importance to the underprivileged children especially in developing countries. Studies of the impact of school facilities on student performance are valuable for developing countries since their education programs often have limited resources (Glewwe et al., 2011). Although school facility data are regularly collected in many developing countries e.g., Vietnam and Guatemala as reported by Attfield and Vu (2013) and Marshall (2009), this type of information was previously unmonitored, incomplete or restricted from public access in the Philippines. Therefore studies with a focus on the country’s school facilities are very few (Alba, 2010b; Lanzona, 2012; Bacolod and Tobias, 2006; Ghuman et al., 2006; Tan et al., 1997). In this thesis, government-provided school facility data of the Philippines collected from 2006-2013 are utilized in an attempt to investigate how the physical environment of school facilities affect student achievement.

Given the necessity of suitable school facilities as venues for learning, this chapter aims to identify which aspect of the facility should be prioritized due to the funding constraints on the establishment of these public resources. Individual socioeconomic status is deliberately omitted as a variable because although the effect of facilities is more significant in developing countries (Husén, 1990; Hanushek, 1995), it is still incomparably small in contrast to these strong predictors of academic achievement (Coleman et al., 1966) especially when aggregated data are used as in the case of this study and in Hanushek and Luque (2003). Instead, this chapter aims to present a study on how physical urban environments affect the academic achievement in developing countries, particularly in the Philippines. The hypothesis is that the imbalanced provision of school facilities might be aggravating the poor performance of children in disadvantaged communities. To support the hypothesis, a case study is presented for Quezon City, the largest city in the Philippines.

According to Perloff (2015), the physical urban environment is generally characterized by five inter-related elements: the natural environment, spatial environment, transportation-utilities environment, neighbourhood environment and
microenvironment. The microenvironment is of vital importance because people spend more time within buildings and inhabited places. Poverty in the urban areas of developing countries such as the Philippines is severe in that even basic health and sanitary facilities are insufficiently provided. *Informal settlements,* also known as slums, have been existing outside the walls of the capital city of the Philippines since the 17th century, however, their exponential growth took place in the 20th century when continuous urban expansion propagated beyond the ancient city walls and development extended to include the 16 surrounding highly-urbanized cities that now comprise the National Capital Region commonly known as Metro Manila (Alcazaren et al., 2010). Informal settlements are areas where “housing units have been constructed on land that the occupants have no legal claim to, or occupy illegally; or housing is not in compliance with current planning and building regulations” (United Nations, 1997, p. 43). *Informal settlers* (i.e. people living in informal settlements) have very limited access to sustainable infrastructure such as safe drinking water, adequate drainage and garbage collection facilities, and reliable emergency/health services (Vlahov et al., 2007). Hence, informal settlements are the main focus in this chapter as they symbolize the most deprived environment among all housing types.

Investigations on how academic performance is affected by the geographical attributes of informal settlements that are prevalent in developing countries are rare in the literature. Many studies have examined the neighbourhood effects of disadvantaged communities on education outcomes in wealthier nations (Ludwig et al., 2001; Webber and Butler, 2007; Dyson and Raffo, 2007; Raffo et al., 2009; Webb-Prather, 2011; Gordon and Monastiriotis, 2006), however, only few papers have investigated student performance in the context of informal settlements and urban schools in developing countries as seen in Stevenson and Chen (1989), Feitosa et al. (2007), Ratan and Tania (2007), Cunha et al. (2009) and Monteiro and Rocha (2013). It is generally understood that poverty levels are lower in urban areas than rural areas (Alkire et al., 2014) since the social and economic infrastructure (i.e., schools, hospitals, roads, electricity, water supply, sanitation, etc.) tends to be available in urban areas. However, in the Philippines, close proximity to urban areas does not guarantee actual access because, for example, fees are required to access goods and services (e.g., water, shelter, use of toilets, transportation) (Satterthwaite, 2003). Therefore, poverty in urban areas is based on low income and sustained by lack of access to facilities. For this reason, Satterthwaite (2003) stated that it is inappropriate to measure poverty levels by income-
based poverty lines which can overestimate poverty in rural areas and underestimate it in urban areas especially for developing countries. This view is echoed by Beall et al. (2000) and Ballesteros (2010) where they described that housing is a better indicator of poverty since city slums suffer from physical and environmental deprivation of facilities.

In this chapter, polygon data of informal settlements and government-provided data of education facilities in the Philippines is utilized. Specifically, attributes of each school’s physical built environment with respect to location, capacity, building condition, provision of basic utilities and available services are analysed. This study focuses on informal settlements which are deprived environments where residents rely on the crowded and poorly maintained spaces that lack access to proper urban facilities. For this reason, Quezon City (see Figure 6-1) was selected as a study area since it has the largest informal settler communities in the country (Cabalfin, 2014). Public elementary schools are selected because it is the most crowded and dilapidated among all the types of schools in the city (Jimenez and Sawada, 2001; Kitaev, 2007).

![Figure 6-1. Study area - the location of Quezon City and informal settlement areas](image)

There are consistent research findings that math scores at young ages are significantly related to adulthood incomes (Niederle and Vesterlund, 2010; Weinberger,
Math scores of economically disadvantaged students were shown to be lowest in many empirical studies (Webb-Prather, 2011; Rothstein, 2013; Balfanz and Byrnes, 2006). This study uses the math score as an important indicator of academic performance. To enhance academic performance, researchers have recommended practical strategies such as reducing the concentration of poverty in schools by keeping school sizes small (although Williams (1990) defined “small” as 300-400 students; for Lee and Loeb (2000) it is less than 400; for Leithwood and Jantzi (2009) it is 300-500), and improving community services and environments (Whipple et al., 2010; Garner and Raudenbush, 1991). However, developing countries have experienced better education outcomes by providing basic facilities such as roofs, walls, floors, desks, chairs, and libraries (Glewwe et al., 2011), which is consistent with some studies conducted in rural areas of the Philippines (Bacolod and Tobias, 2006; Ghuman et al., 2006; Tan et al., 1997). Therefore, one of the main objectives in this chapter is to investigate the best approach to promote academic performance in the context of urban poor communities in the Philippines.

### 6.2 Study Area and Data

Metropolitan Manila is the most populous region in the Philippines. Quezon City is one of the 16 highly-urbanized cities that form Metropolitan Manila. It is the most populous city in the country and represents 25% of Metropolitan Manila’s land area and population. Quezon City is composed of 142 barangays (towns or suburbs in Filipino) which are grouped into six legislative districts. A large amount of informal settlements are caused by the concentration of job and education opportunities in Metropolitan Manila. Quezon City is chosen for this study as it holds the majority (40%) of Metropolitan Manila’s slum communities based on the July 2011 estimates from the National Housing Authority of the Philippines (Housing and Urban Development Coordinating Council, 2014). Quezon City was once designated as the capital city when the country gained independence from the United States. In an effort to decongest the historic centre of Manila, the farmland 20 km away became the new seat of government (Carunungan, 1982; Duldulao, 1995; Caoili, 1999). Construction of public infrastructure in the newly-established capital city required a massive labour

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23The population of Quezon City at the 2010 Census was 2.7 million.
force but the government failed to address housing for the workers which led to the creation of informal settlements (Lu, 2010). Quezon City now holds the majority of slum settlements in Metro Manila because the informal settlements occupied vacant lots that were allotted for government buildings and other public infrastructure (e.g., highways) but remain unutilized (Cabalfin, 2014).

In the Philippines, informal settlers organize themselves in order to acquire utilities and government services (Lagman, 2012). In fact, they contribute to the nation politically as a significant source of votes and economically as a source of labour (Berner, 2001; Cabalfin, 2014). Although at least 50% of Metropolitan Manila’s informal settlers have jobs and pay taxes (Ballesteros, 2010), they still prefer to live in the informal settlement areas within the city primarily due to its close proximity to their workplace (Ragragio, 2003). Half of the labour force living in informal settlements are employed in the formal sector while the rest engage in informal employment such as domestic help, tricycle driving, construction labour and vending (Ragragio, 2003). Government housing and relocation areas are unattractive because they are often far flung denoting higher transportation costs.

**School Mean Math Scores**

The dependent variable in the global and local regression models is the overall mean math score for each school which was sourced from the Quezon City Division Achievement Test. This test is administered to public elementary school pupils in Grades 1, 2, 4, and 5 as a preparation for the National Achievement Test which is given to students in Grades 3 and 6. Reports for the school year 2007-2008 was selected because 80% of school facility data for public elementary schools of Quezon City were prepared during this period. The report contains the mean percentage of mastery of each public elementary school for Math, Science, English, Filipino, and History. The mean math score for School $i$ ($Math_i$) is computed by taking the arithmetic mean of the mean math scores for Grades 1, 2, 4 and 5.

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24 In the Philippines, children start primary school at age 6.
25 Only 20% of the elementary schools in Quezon City gave an updated report of their school facility data in 2011.
Selection of School Facility Variables and Data Preparation

A database of school facility features was sourced from DepEd Philippines. The data were collected by the department’s SMU through a survey form that was distributed to all public schools and filled out by the school administrators. 83 out of Quezon City’s 97 public elementary schools—an overwhelming majority—responded to the survey.

First, the Pearson correlation was utilized to narrow down and identify candidate variables pertaining to school facility features which were significantly related to math scores. IBM SPSS Statistics 22 was utilized in this step where 20 variables pertaining to poverty locations, building conditions, school services, and school capacity were isolated from the database with over 60 variables pertaining to attributes of public school facilities (i.e., location, accessibility, capacity, utilities, services, equipment, and facility condition).

Next, as described in Section 3.2, a data mining tool was utilized to evaluate which is the best combination among the 20 selected variables in the aim to predict math scores. Equation (6-1) displays the coefficient estimates of the selected model. It has the best combination of variables as it has the highest Adjusted $R^2$ (0.23) and lowest Akaike’s Information Criterion (AICc) (513.4) value. All the parameter coefficients have p-value < 0.05, meaning that they are statistically significant i.e., the coefficients actually reflects the characteristics of the population rather than just sampling error. There is no multicollinearity (i.e., redundancy) among the variables as the variance inflation factor (VIF) is less than 7.5. The model’s Jarque-Bera p-value is greater than 0.10, indicating that it has normally distributed residuals, and there is no model bias. Table 6-1 shows the t-test results and Moran’s I values of the selected variables. It

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26 Size (area) of informal settlements, intensity of poverty (kernel density estimation of informal settlements), school location within poverty hotspot/coldspot, school’s proximity to the central business district, town’s commercial land value and population size.
27 School’s mean building condition score.
28 Presence of a school library, health clinic and canteen.
29 Total school buildings, total classrooms by type, ratio of total pupils to total classrooms, total teachers, total toilets by type and ratio of pupils to toilets by gender.
30 Exploratory regression in ArcMap 10.3.
31 In regression models, residuals are often used to measure the differences between the actual data and the models. In this study, the residual represents the difference between the actual math score of school $i$ and the estimated math score from Equation 6-1.
indicates that all the variable coefficients have significant t-values and only the IS variable is clustered.

**Table 6-1.** T-test results and Moran’s I for each indicator.

<table>
<thead>
<tr>
<th>Variable</th>
<th>t-Statistic</th>
<th>Moran’s I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher</td>
<td>-3.24</td>
<td>0.33</td>
</tr>
<tr>
<td>Room</td>
<td>2.73</td>
<td>0.19</td>
</tr>
<tr>
<td>BC</td>
<td>-3.04</td>
<td>-0.42</td>
</tr>
<tr>
<td>Clinic</td>
<td>2.17</td>
<td>-0.23</td>
</tr>
<tr>
<td>IS</td>
<td>2.75</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Finally, the model passes Global Moran’s I statistic for spatial autocorrelation, meaning that the residuals are randomly distributed in the study area. All the independent variables were rescaled according to the dependent variable so that the contribution of each variable can be compared to that of the dependent variable.

\[
\text{Math}_i = 85.31 - 0.07 \text{Teacher}_i + 0.16 \text{Room}_i - 0.43 \text{BC}_i + 3.14 \text{Clinic}_i + 0.01 \text{IS}_i
\]

Equation (6-1)

where the coefficient parameters were estimated based on the data of 83 public elementary schools. The number of classrooms \((\text{Room}_i)\) and the number of schoolteachers \((\text{Teacher}_i)\) for School \(i\) determine the capacity of the school facility at any point in time. The coefficients of Equation (6-1) indicate that, for every classroom, mean school Math scores increase by 0.16 points. However, it decreases by 0.07 points for every teacher. This characteristic of public elementary schools in Quezon City is discussed further in Section 6.3 and presented in Table 6-3. The mean building condition score \((\text{BC}_i)\) represents the overall state of the school’s buildings as assessed by the school’s administrator. As mentioned in Section 5.1, the buildings are assessed as either ‘good’, ‘needs repair’, or ‘dilapidated’. A numeric value is assigned to each building where a higher building condition value \((\text{BC})\) indicates a better school building, as defined in Equation (6-2). The assigned numeric values reflect the hypothesized relationship with the dependent variable where higher math scores should be expected from better building conditions. This is the reverse of assigned building condition values in Section 5.1 where lower values indicate better buildings which is
consistent with the expected behaviour of other variables considered in that chapter (i.e., lower values are more desirable).

\[
BC = \begin{cases} 
30, & \text{good} \\
20, & \text{needs repair} \\
10, & \text{dilapidated}
\end{cases}
\]  
Equation (6-2)

Since a public school in the Philippines usually has four buildings, the mean value is calculated as in Section 5.1 to obtain one building condition value per school [see Equation (6-3) for the details].

\[
BC_i = \frac{\sum_{j=1}^{m} BC_{i,j}}{m}
\]  
Equation (6-3)

where \(BC_i\) is the building condition score for School \(i\), \(BC_{i,j}\) is the building condition score for a building \(j\) within School \(i\), and \(m\) is the total number of buildings within School \(i\). Roughly 60% of the school buildings in the study area are in good condition but around 5% are dilapidated. The coefficients of Equation (6-1) indicate that better building conditions pull down mean school Math scores by 0.43. It seems that larger budget allocations for big schools, which are signified by better building conditions, are not enough to pull up Math scores in the context of Quezon City’s public elementary schools.

The presence of a school health clinic (\(Clinic_i\)) is represented in the data as given in Equation (6-4).

\[
Clinic_i = \begin{cases} 
0, & \text{no Clinic} \\
1, & \text{with Clinic}
\end{cases}
\]  
Equation (6-4)

The coefficients of Equation (6-1) indicate that mean school Math scores increase by 3.14 with the presence of a school health clinic. It should be noted that this school amenity is not provided to each school. The maintenance of this service involves collaborations between the schools and local government units. Public education institutions are not obligated to ensure student health and well-being since health services are normally provided by separate government and private institutions. This lack of commitment is confirmed by the absence of national standards for recommended ratios of school nurses per child in the Philippines and even in other developed countries such as the United States of America (Delisio, 2010). Efforts to coordinate the activities of the centralized education sector and the decentralized health sector in the
Philippines are particularly difficult due to differences in organizational structure (Benzian, 2012).

**Informal Settler Communities**

The area of informal settlements near a school was selected as an independent variable due to increasing evidence that the spatial concentration of disadvantaged areas affects education outcomes (Dyson and Raffo, 2007; Lupton, 2004; Raffo et al., 2009). In Quezon City, families are segregated by income not only through place of residence but also through school choice. As mentioned earlier, more than 50% of informal settlers in the Philippines are educated income earners. Therefore some families will have the means to send their children to fee-paying private schools even though they are living in disadvantaged communities. Private elementary schools are desirable because they consistently have higher mean percentage scores in national achievement tests than their government counterparts (Lam, 2005). Therefore those who can only afford to send their children to the public elementary schools are underprivileged not only by living in disadvantaged communities but also by relatively lower earnings. Due to young age and limited income to pay for transportation, children attending public elementary schools live in nearby informal settlements. The size and proximity of informal settlements to a school is an indicator of not only the size of the school but also the number of disadvantaged families living near the school. According to Lam (2005), 61% of students attending public elementary schools of the Philippines are classified as poor, meaning their households belong to the lowest and second income quintiles while those in the highest income quintile only form 6% of the enrollees. Polygon data that represent informal settlement communities were utilized to determine the area of the communities which are in closest proximity to each school location point ($IS_i$). It is based on Equation (6-5):

$$IS_i = Area (IS_{\text{min}(d_{iJS}))}$$

Equation (6-5)

where $d_{iJS}$ is the Euclidean distance between School $i$ and an informal settlement community $IS$. The coefficients of Equation (6-1) indicate that the Math scores of the schools increase by 0.01 per square kilometre area of the nearest informal settlement community. As mentioned in Section 6.1, studies on the relationship between disadvantaged communities and education outcomes find that proximity to large
concentrations of poor communities decrease academic performance. Hence this unusually positive coefficient is noteworthy and will be explored in the next sections.

6.3 Global and Local Statistics

In order to explore the spatial variation of deprived physical urban environments and its effect on academic achievement, the global regression model specified in Equation (6-1) is investigated. First, Local Moran’s I (LMI) analysis was employed to investigate how location is related to academic performance and the physical environment of public elementary schools. Second, GWR was used to ascertain whether the fixed relationships utilized in Equation (6-1) vary throughout the study space or not. Finally, this study investigated whether academic performance is affected by fixed and spatially varying predictors through the use of semi-parametric GWR (S-GWR). The methods are summarized in Table 6-2.

<table>
<thead>
<tr>
<th>Method 1: OLS with LMI</th>
<th>5 fixed predictors and 2 local indicators of clustering given in Equation (6-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 2: GWR</td>
<td>5 spatially varying predictors given in Equation (6-8)</td>
</tr>
<tr>
<td>Method 3: S-GWR</td>
<td>3 fixed predictors and 2 spatially varying predictors given in Equation (6-9)</td>
</tr>
</tbody>
</table>

Table 6-2. Summary of methods utilized

Method 1: School Characteristics and Poverty Hot spots in Quezon City

Disadvantaged areas in Quezon City were identified through LMI and the polygon data of informal settlements. LMI values can be interpreted as hot spots similar to the Getis Ord Gi, or outliers similar to Anselin-Moran’s scatterplot (Anselin, 1996). In this method the school characteristics are explored in relation to the spatial concentration of disadvantaged areas.

First, a uniform grid of over 180,000 points in 10-meter spacing was constructed using QGIS 2.2.0 to achieve a raster representation of deprived areas in the city from

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32 Most dwellings in informal settlements are 3 meters apart but some can be 15 meters apart if the lots are unusually large and if the alleys (which do not follow rigid rules and is
the polygon data of informal settlements. Next, intensity in the informal settlement clustering was assessed through KDE in ArcMap 10.3 as the points were transformed into a map of smooth estimates. Finally, LMI was employed to classify and identify informal settler clusters and outliers as follows: HH denotes poor areas surrounded by poor areas; HL are poor areas surrounded by rich areas; LH are rich areas surrounded by poor areas; LL are rich areas surrounded by rich areas; and NS are areas with no significant clustering.

Figure 6-2 shows the schools marked based on the LMI classifications of informal settlements in the study area. The schools fell in only 3 of the cluster areas (i.e., HH, NS, and LL).

![Figure 6-2. Poverty clusters and public elementary school locations in Quezon City. (NS - not significant, HH – hotspot of poverty i.e. poor areas, HL - poor areas surrounded by rich areas, LH – rich areas surrounded by poor areas, and LL – cold spot of poverty i.e. rich areas)](image)

Table 6-3 describes the dynamics of public elementary education in urban areas of the Philippines. It demonstrates that cost-free public schools primarily attract the urban poor. Schools within poverty hot spots are larger in size (i.e., higher mean number of spontaneously allocated as the need arises over a period of time), streets, and shared open spaces for laundry or gardening are accounted for (Cabalfin, 2014).
rooms and teachers at 48.25 and 113.56 respectively), indicating that proximity to informal settlement communities is associated with larger student enrolment in public elementary schools of Quezon City. Since the government of the Philippines allocates funds based on a public school’s size, large schools near the poverty hot spots may have more resources to maintain better building conditions which may explain their higher mean building condition score at 25.98. On the other hand, schools located in cold spots of poverty will have lower enrolments and less funds to tap into. Fewer and smaller informal settlements (mean area of 19,100 m²) in the school’s vicinity are also shown in schools with reduced student populations. Table 6-3 also indicates that, on the average, schools in the hot spots of poverty have a mean math score of 77.67 which is 3.18 points lower than the average math score of schools in the cold spots. Despite their large population that denotes higher government funding, only 44% of schools in the hot spots had clinics as opposed to 75% of schools in the cold spots. It also shows that, for Quezon City, larger schools have larger pupil-teacher ratios than smaller schools (see Figure 6-3).

Table 6-3. Descriptive characteristics of government elementary schools in Quezon City

<table>
<thead>
<tr>
<th>Local Statistics (LISA)</th>
<th>Mean area of nearest informal settlement (x 1000 sqm) (IS)</th>
<th>Mean number of Teachers / school (Teacher)</th>
<th>Mean number of Rooms / school (Room)</th>
<th>Mean Bldg Cond Score (BC)</th>
<th>% of Schools with Clinics (Clinic)</th>
<th>School Mean Math Score (Math)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot spot of poverty (HH)</td>
<td>308.11</td>
<td>48.25</td>
<td>113.56</td>
<td>25.98</td>
<td>44%</td>
<td>77.67</td>
</tr>
<tr>
<td>No significant clustering (NS)</td>
<td>48.75</td>
<td>35.83</td>
<td>56.44</td>
<td>25.34</td>
<td>76%</td>
<td>78.60</td>
</tr>
<tr>
<td>Cold spot of poverty (LL)</td>
<td>19.10</td>
<td>35.13</td>
<td>37.38</td>
<td>24.97</td>
<td>75%</td>
<td>80.85</td>
</tr>
</tbody>
</table>
The effects of the physical environment were further investigated by adding two variables representing poverty hot spots (HH) and cold spots (LL) to the five variables in Equation (6-1). The modification is given in Equation (6-6):

\[
\text{Math}_i = 84.91 - 0.07 \text{Teacher}_i + 0.15 \text{Room}_i - 0.42 BC_i + 3.14 \text{Clinic}_i + 0.01 IS_i - 0.39 HH_i + 1.23 LL_i
\]

Equation (6-6)

where the coefficient parameters were estimated based on the data of 83 public elementary schools and the other variables are as defined in Equation (6-1).

The coefficients of Equation (6-6) indicate that math scores decrease by 0.39 points when schools are located in hotspots of poverty but increase by 1.23 points when schools are located in cold spots of poverty. Unfortunately, adding variables that represent poverty hot spots does not help in the estimation of math scores [i.e., Equation (6-6) had a higher AICc value (517.9) compared to Equation (6-1) as shown in Table 6-6].

6.4 Regression Modelling

Method 2: GWR Modelling

The stationarity of Equation (6-1) is verified through GWR which is a local form of linear regression used to model spatially varying relationships where the coefficients depend on the variable’s geographic location (Brunsdon et al., 1996). It is a diagnostic
tool used to indicate a problem with global models (Fotheringham, 2009). The challenge in local regression models is identifying the appropriate bandwidth size. Larger bandwidths contain more samples so they give weaker approximations, but the standard deviation is smaller. On the other hand, choosing smaller bandwidths gives better approximations but the standard deviations are larger. The golden section search function of the GWR 4.0 tool was used to compute for the bandwidth size. The optimal size was determined by selecting the model with the lowest AICc values. To estimate the geographical weights of local coefficients, this study utilized a fixed bi-square kernel weighting formula [see Equation (6-7)]. Bi-square kernels are suitable for clarifying local extents for model fitting due to its clear-cut range with non-zero kernel weights (Nakaya, 2014).

\[
    w_{ij} = \begin{cases} 
    \left(\frac{1 - d_{ij}^2}{\theta^2}\right)^2, & d_{ij} < \theta \\
    0, & d_{ij} > \theta 
    \end{cases} \tag{6-7}
\]

where \( w_{ij} \) is the weight value of the observation at location \( j \) for estimating the coefficient at location \( i \), \( d_{ij} \) is the Euclidean distance between \( i \) and \( j \), and \( \theta \) is a fixed bandwidth size defined by a distance metric measure.

Spatially varying coefficients depending on the geographical coordinate of the location \( u_i = (x_i, y_i) \) were applied as given in Equation (6-8):

\[
    Math_i = \sum \alpha_0(u_i) + \sum \alpha_3(u_i)Teacher_i + \sum \alpha_2(u_i)Room_i \\
    + \sum \alpha_5(u_i)BC_i + \sum \alpha_4(u_i)Clinic_i + \sum \alpha_6(u_i)IS_i \tag{6-8}
\]

where the coefficient parameters \( \alpha \) were estimated based on the data of 83 public elementary schools and the variables are as defined in Equation (6-1). The coefficients vary depending on the geographical coordinate of the school \( u = (x_i, y_i) \) as summarized in Table 6-4. Table 6-4 indicates that the Clinic variable has the largest spatial variation with values ranging from 2.86 to 3.95 depending on the location to be estimated. This was unexpected due to the assumption that all public school facilities within the city should be homogeneous. It also indicates that the Teacher variable has no spatial variation as the coefficients remained at -0.07. This was unexpected as well because schools near poverty hotspots had significantly larger pupil-teacher ratios than
schools in other areas of the city and larger pupil-teacher ratios are known to negatively affect the academic performance of elementary students (Angrist and Lavy, 1997; Borland et al., 2005; Rivkin et al., 2005; Finn and Achilles, 1999; Funkhouser, 2009; Nye et al., 2000). Hence it is seen that some variables in the model are unexpectedly stationary (i.e., $Teacher_i$) while some are unexpectedly spatially varying (i.e., $Clinic_i$).

The calculated bandwidth that gave the best result was the maximum bandwidth (17 km) and contained all samples, which was essentially the scope of Equation (6-1) where the result was achieved when all the points were considered. Hence, GWR was unable to gain better estimates by considering subsamples of the study area and forcing all variables to vary spatially. The inferior performance of Equation (6-8) is evidenced by its weaker AICc value (515.35) as compared to the other equations in Table 6-6. This signifies that GWR is not a suitable method when variables pertaining to the physical built environment are utilized to estimate math scores. Furthermore, Moran’s $I$ values in Table 6-1 indicate that only the IS variable is clustered. Hence we have investigated whether S-GWR models can provide better estimates when spatially clustered and spatially random variables are used.

### Table 6-4. Summary statistics for varying (local) coefficients in Equation (6-8)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>STD</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>84.28</td>
<td>1.35</td>
<td>83.95</td>
<td>85.06</td>
<td>87.65</td>
</tr>
<tr>
<td>Total teachers</td>
<td>-0.07</td>
<td>0.00</td>
<td>-0.07</td>
<td>-0.07</td>
<td>-0.07</td>
</tr>
<tr>
<td>Total rooms</td>
<td>0.15</td>
<td>0.01</td>
<td>0.12</td>
<td>0.15</td>
<td>0.18</td>
</tr>
<tr>
<td>Building condition score</td>
<td>-0.44</td>
<td>0.02</td>
<td>-0.48</td>
<td>-0.44</td>
<td>-0.41</td>
</tr>
<tr>
<td>IS</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Clinic</td>
<td>3.30</td>
<td>0.24</td>
<td>2.86</td>
<td>3.30</td>
<td>3.95</td>
</tr>
</tbody>
</table>

### Method 3: S-GWR Modelling

The coefficients of Equation (6-8) shown in Table 6-5. have indicated that some variables are spatially varying while others are not. Hence semi-parametric Gaussian GWR modelling (S-GWR) is employed as it allows stationary and non-stationary variables to be combined. S-GWR was developed as an extension of GWR that allows mixing of geographically varying and fixed coefficients in a generalized linear model. That is, it combines global and local explanatory variables to predict the dependent variable (Nakaya et al., 2009). Coefficient estimates, model diagnostics, and “golden search” bandwidth sizes can be automatically computed using GWR 4.0 (Nakaya et al., 2009). By comparing model improvements when variables are changed from
geographically varying to fixed and vice versa, the tool can select and recommend a model that best represents the data.

Fixed and spatially varying parameters were identified by performing geographical variability tests for each of the independent variables in Equation (6-1). The model with the lowest AICc value was selected after comparing a series of models that estimated the weights of the local coefficients. The best bandwidth size is 6.4 km as a result of a fixed bi-square kernel weighting function and a “golden section” search routine. This distance covers approximately 75% of the study area. The best model (i.e., lowest AICc) that combines fixed and geographically varying coefficients to predict school performance is given in Equation (6-9):

\[
Math_i = 83.69 - 0.08 \text{Teacher}_i + 0.17 \text{Room}_i - 0.39 \text{BC}_i + \sum \alpha_4(x_i, y_i)\text{Clinic}_i + \sum \alpha_5(x_i, y_i)\text{IS}_i
\]

Equation (6-9)

where the coefficients of IS\(_i\) and Clinic\(_i\) vary depending on the geographical coordinate of the school \(u = (x_i, y_i)\). The coefficients of the Teacher\(_i\), Room\(_i\), and BC\(_i\) variables are fixed as indicated in Equation (6-9) while the coefficients of the geographically-varying IS\(_i\) and Clinic\(_i\) variables are summarized in Table 6-6.

<p>| Table 6-5. Summary statistics for varying (local) coefficients in Equation (6-9) |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>STD</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS</td>
<td>0.00</td>
<td>0.02</td>
<td>-0.03</td>
<td>0.00</td>
<td>0.06</td>
</tr>
<tr>
<td>Clinic</td>
<td>3.57</td>
<td>1.53</td>
<td>-0.45</td>
<td>3.77</td>
<td>7.22</td>
</tr>
</tbody>
</table>

The utilization of S-GWR wherein only the informal settlement and school clinic variables are geographically varying provided a slight improvement to Equation (6-1) with its lower AICc and higher Adjusted R\(^2\) values (see Table 6-6).

<p>| Table 6-6. Comparison of regression model performance |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Method</th>
<th>OLS Eq (6-1)</th>
<th>1: OLS and LMI Eq (6-6)</th>
<th>2: GWR Eq (6-8)</th>
<th>3: S-GWR Eq (6-9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R(^2)</td>
<td>0.29</td>
<td>0.29</td>
<td>0.32</td>
<td>0.42</td>
</tr>
<tr>
<td>Adjusted R(^2)</td>
<td>0.23</td>
<td>0.21</td>
<td>0.22</td>
<td>0.30</td>
</tr>
<tr>
<td>AICc</td>
<td>513.40</td>
<td>517.90</td>
<td>515.35</td>
<td>510.78</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>NA</td>
<td>NA</td>
<td>17km</td>
<td>6.4km</td>
</tr>
<tr>
<td>N</td>
<td>83.00</td>
<td>83.00</td>
<td>83.00</td>
<td>83.00</td>
</tr>
</tbody>
</table>
The geographic variability tests identified the \( IS_i \) parameter as non-stationary (diff-criterion = - 4.7). However, the assessment of \( Clinic_i \) as non-stationary, although it was weak (diff-criterion = - 0.45), was surprising. Since all the data samples were public schools, it was expected that the government would provide the same facilities to every school. Equation (6-9) achieves better estimates as it allows the informal settler and school clinic variables to become non-stationary. Hence S-GWR was able to contribute new insights to the situation by assessing the stationarity and non-stationarity of each variable. It was able to detect that some of the variables were spatially varying, which was not observable from OLS and GWR techniques. This method achieves better estimates by combining the fixed and spatially varying parameters in one equation. Estimated Math scores using the GWR approach in Equation (6-8) yielded slightly worse estimates than its OLS counterpart in Equation (6-1) even though the scope of both equations is essentially the same (i.e., the entire study area). The random residuals of Equation (6-1) signify that it is already a properly-specified model and further evaluation using GWR is unnecessary, hence the low improvement in model fit between the two equations. However, evaluation through S-GWR might be useful due to the presence of spatially clustered and spatially random variables in the model. Table 6-6 indicates that the best model is based on Equation (6-9) where only the \( IS \) and \( Clinic \) variables are allowed to vary spatially and the spatially varying coefficients are estimated within a radius of 6.4km using S-GWR. The 7-point difference in AICc values indicate that there is a significant difference in performance between the semiparametric form in Equation (6-9) and the traditional OLS form in Equation (6-6) where all variables are fixed and substitutes for locations are added to the mix. The success of the semiparametric model might be due to the unmistakable effect of neighborhoods and socioeconomic conditions not only to academic performance but also on school facilities and services in the case of Quezon City.

Figure 6-4a illustrates the spatial variation in the \( R^2 \) values of Equation (6-9). Math scores are predicted with the same accuracy (i.e., \( 0.22 \leq R^2 \leq 0.32 \)) in the southern areas by Equations (6-1), (6-6), and (6-9). However, better estimates for northern areas were achieved with Equation (6-9). Adjusted \( R^2 \) values between 0.2 and 0.3 are expected in education production functions that utilize school resource variables to
measure education outcomes as given by the results of other similar studies (Hanushek and Luque, 2003; Jimenez and Paqueo, 1996; Tan and Paqueo, 1989).

Parameter estimates for locations with statistically significant t-values of the spatially varying IS and Clinic variables are illustrated in Figure 6-4b and Figure 6-4c respectively. The mapping technique for presenting GWR results in this way is adapted from Matthews and Yang (2012). Shades of blue in Figure 6-4 indicate higher values and shades of green indicate lower values.

The $IS_i$ parameter estimate was able to predict math scores more effectively ($t$-value $\geq 1.96$) in the northeast areas where the largest poverty hot spot is located (see Figure 6-4b). Surprisingly, local coefficients in this zone are not only positive but also statistically significant. This indicates that the size of informal settlements is not the cause for the low math scores that were observed in this poverty hotspot. Although this result is controversial, it is not surprising because of the fact that most informal settlers in Metro Manila are educated income earners and education is perceived as a means to escape poverty. Hence it can be argued that perhaps, in the case of Quezon City, families residing in these larger concentrations of disadvantaged areas are more academically competitive than the families residing within the smaller and disaggregated informal settler communities.

The $Clinic_i$ parameter effectively predicted math scores among schools in the northwest areas but seemed to be insignificant ($-1.96 < t$-value $< 1.96$) in the large poverty hot spots in the northeast areas (see Figure 6-4c). Local coefficients indicate that the presence of a school clinic is able to increase math scores by 3.5 points on the average. The results of this study indicate that the uneven provision of public education resources such as health clinics and teachers, not the poverty hotspots per se since most students attending public elementary schools of Quezon City come from poor families, are affecting the poor performance of the elementary students in the poverty hotspots of Quezon City.
Figure 6-4. SGWR modelling results. The spatial variation of the: (a) local \( R^2 \), (b) statistically significant IS parameter estimates, and (c) statistically significant Clinic parameter estimates.
6.5 Academic Performance of Children in Deprived Urban Environments

Most of the students that attend Quezon City’s public elementary schools live in informal settlements near their schools, while those who have the means will strive to send their children to private schools. Private elementary schools are the first choice for many who can afford them. The few government-funded public elementary schools are perceived to be of lower quality and primarily cater to the very poor. After identifying poverty hot spots through Local Moran’s I, this study found lower mean math scores for public elementary schools located in deprived physical urban environments. This is not surprising and generally supports much of education literature wherein proximity to locations with poor socioeconomic conditions correlates with lower academic performance. Schools in the poverty hot spots were also found to be larger and significantly lack school clinics but have better building conditions. The study also found that pupil-teacher ratios are not equal across all public elementary schools and are higher for schools located within hotspots of poverty.

The regression models of this study indicate that the primary predictors of higher math scores among public elementary schools that serve disadvantaged families in Quezon City are lower pupil-teacher ratios and the presence of school health clinics. Higher math scores are associated with larger schools. These schools are characterized by close proximity to poverty hotspots and large numbers of classrooms. The advantage of large schools supports the findings of Gardner et al. (1999), Schneider et al. (2006), Werblow and Duesbery (2009), and Vorthmann (2011). It is contrary to other studies that suggest large schools benefit affluent students while poorer students benefit from small schools (Friedkin and Necochea, 1988; Howley and Howley, 2004; Leithwood and Jantzi, 2009). Although there is no consensus as to the effect of school size on education achievement according to Slate and Jones (2005). The identification of other variables that are possible mediators in the relationship between school size and academic performance is beyond the scope of this study.

All of the parameter estimates associated higher math scores with poorer building conditions. Although the schools in Quezon City’s cold spots of poverty have higher math scores, inferior buildings are associated with them due to small enrolments. Hence in the context of public elementary schools that serve the urban poor of Quezon City,
low pupil-teacher ratios are more significant in elevating math scores than the provision of better building conditions.

The study also found that basic school facilities such as clinics are significant in the aim to support academic achievement for urban poor communities experiencing deprived physical urban environments. Similarly, the result of James (2009) showed strong relationships between educational attainment and overall health in the USA. All of the regression estimates associated higher math scores with the presence of school clinics. The significant lack of clinics among schools located in the hot spots of poverty was unexpected since all public elementary schools are maintained by the government and it was presumed that most schools, if not all, would have clinics.

In urban poor communities, children experience higher community risk factors (i.e., becoming victims of crime and living in unsanitary environments that cause health problems). Children living in urban poverty have greater health risks due to toxics, pollutants and heavy traffic (Bartlett, 2011). Earlier in life, they are exposed to health problems and are prone to low academic performance which can affect their future opportunities (Caspi et al., 2000; Raffo, 2013). In urban areas of the Philippines, Racelis and Aguirre (2002) stated that disadvantaged children are often unable to attend school due to the adversarial environments even though they understand the importance of education. In the Philippines, the poor can only afford to visit free or low cost clinics and health centres to receive medical attention. Therefore the attractiveness of schools that have clinics may be due in part to the lack of accessible basic health care facilities for informal settlers. This finding is important as it provides a key aspect in the provision of appropriate government programs that address the needs of informal settlers in Quezon City. Since schools are considered as a child’s second home, the government is in a position to improve the aptitudes of these children just by ensuring that they can access facilities like clinics and other basic health and sanitary amenities through their school (i.e., toilets, lavatories, etc.). Even simple school-based health improvement programs such as washing hands, brushing teeth, and deworming has been proven to provide significant impact in improving the health conditions of public school students in the Philippines (Monse et al., 2013; Zimmermann, 2009; Monse and Yanga-Mabunga, 2001). Since these initiatives may also improve academic achievement, it is troubling that financial resources for school health programs are decreasing and commissioned school medical personnel remain insufficient in the country (HealthDev Institute, 2013). According to Batley and McLoughlin (2015), preventive healthcare is
one of the services with the lowest political importance as opposed to other school utilities such as sanitation, water and electricity services. As it is the last priority, only more affluent districts can afford to provide this service. Further study is needed to investigate what it means to provide a clinic within a public elementary school in the very impoverished areas, such as the informal settlement areas of Quezon City in the Philippines’ context.

To the best of the authors’ knowledge, this is the first study that used S-GWR to evaluate the relationship between academic performance and the physical urban environment, and the first that utilized informal settler locations in evaluating this relationship for schoolchildren in deprived environments. The nature of the data utilised for this study led to the conclusion that semi-parametric models which allow the combination of fixed and spatially varying predictors in regression models are beneficial to understand the assortment of factors that contribute to academic achievement.

Deprived areas are spatially clustered and not evenly distributed over the urban landscape due to urban spatial segregation (Herbert, 1972). Hence, slum communities are expected to be non-stationary. Conversely, public school facility data are stationary since infrastructure and resources should be homogenous and equally provided by the government to all schools. However, geographical variability tests in S-GWR revealed that the distribution of school clinics was spatially varying and was more common among schools located in more affluent regions. The method was able to detect weak spatial patterns in the provision of school clinics that were otherwise not visible in other regression methods. Regression modelling through OLS is not able to capture this phenomenon as it forces all variables to be stationary. GWR is also unable to provide better results as it forces all variables to be non-stationary. In the context of the data used for this study, the ability of S-GWR to allow stationary and non-stationary variable coefficients was advantageous and provided the best result in the estimation of the relationship between academic achievement and the physical urban environment. The model performs better in the north of the city where larger informal settlement communities are located.

This study is limited by the availability of socioeconomic, environmental, and academic data for each student. Moreover, actual class size and school double shift data are useful but unavailable for analysis. The homogeneity of structures in the selected city may be the source of the insignificant correlations of math scores to other variables
pertaining to school facilities (e.g., libraries, utilities, etc.). In the next chapter, more cities and provinces are included for a more heterogeneous school facility data that will allow further analysis of other facility variables. A larger scope will likewise enable the analysis of more samples which is advantageous to GWR modelling (Páez et al., 2011).
Chapter 7
Investigating the Relationship between School Facilities and Academic Achievements through Geographically Weighted Logistic Regression

This chapter attempts to understand the challenges faced by Philippine public schools located far from the capital and the means to address them. In their review of papers related to education resources and education outcomes, Glewwe et al. (2011) has recognized that the best solution for education resource allocation will vary even within countries. Therefore future research should try to identify the best strategy for each situation. As stated in Chapter 1, a threshold has to be identified where it is beneficial to pay attention to the improvement of school facilities in the case of the Philippines.

This study adds to the body of knowledge by identifying aspects of the school facility that should be prioritized given the social and environmental conditions of a district. This chapter aims to address the following questions: (1) Which aspect of the school facility is correlated with the top performing schools? (2) Given that the needs of each school will vary depending on their current situation, how can stakeholders determine which aspect to prioritize for management and maintenance? (3) Which school facility variables have fixed or spatially-varying effects across the study area?

The next section describes the study area and how it was selected. In section 7.3 the logistic form of semiparametric GWR is introduced as an appropriate method based on the nature of the dependent variable. Model variables and regression results are detailed in Section 7.4.

7.1 Study Area and Data

The dependent variable in the logistic regression models represents the presence or absence of a public elementary school in the list of top performing schools as

\[\text{The list was acquired from the National Education Testing and Research Centre (NETRC) of the Philippines.}\]
indicated in Equation (7-1). The location of the top performing school hotspots are indicated in Figure 7-1a. As mentioned earlier, the top performers are defined as schools with mean overall scores above 75 in the National Achievement Test.

\[
TopSch_i = \begin{cases} 
1, & \text{school mean overall score} \geq 75 \\
0, & \text{school mean overall score} < 75 
\end{cases} 
\text{Equation (7-1)}
\]

Government-provided data from various years were combined for this study. School facility data were accumulated from the years 2006 to 2012. School mean overall scores are as of 2009. Grade 6 data were analysed because it is only the test that is administered at both public and private elementary schools. Government personnel data (e.g., teachers) were collected in 2012. Water and electricity sources of public elementary schools are indicated as of 2013. In the database of school facility features used for this study, only 55% of the public elementary schools have location coordinates. The study was restricted to the provinces where more than 60% of schools have GPS coordinates. In this way bias is minimized because generalizations about the school facilities will be relevant to the majority of the school facilities in the province. The locations of the selected provinces are shown in Figure 7-1b.

The eight adjacent provinces in the eastern seaboard (see Figure 7-1c) were selected as the study area because they form the largest cluster of provinces with well-mapped schools (e.g., more than 60% of all schools, including top performing schools, have location coordinates). Although this region is a top performing school hotspot (see Figure 7-1a), the state of the school facilities in these provinces are only considered average (Figueroa et al., 2016). The provinces in this region are primarily agricultural areas, but mining and fishing also provide significant revenues. The northern provinces in the study area, Leyte and Samar, is called the stormy east while the southern provinces, Surigao and Agusan, is a mountainous area situated beside the deepest point in the country, the Philippine Trench. Established education institutions in this part of the country are located in the highly urbanized cities of Tacloban (located in Leyte, light green polygon in Figure 7-1c) and Butuan (located in Agusan del Norte, dark blue polygon in Figure 7-1c).

34The school facility data was collected by DepEd Philippines SMU through a survey form that was distributed to all public schools and filled out by the school administrators.

35In the Philippines, towns are classified as cities if it complies with income and population or land area requirements as stated in the Local Government Code of 1991.
Figure 7-1. The location of: (a) top performing school hot spots, (b) provinces with well-mapped schools where more than 60% of schools have GPS coordinates - the clusters are indicated in the boxes and (c) the study area, which is the largest cluster of provinces with well-mapped schools.
7.2 Local Statistics

Model Variables

Similar to what was done in Section 6.2, the Pearson correlation was used to narrow down and identify variables pertaining to school facility features which were significantly common among the top performing schools in the study area. IBM SPSS Statistics 22 was utilized in this step where eight variables pertaining to school services, capacity and accessibility were isolated from the database with over 60 variables on the attributes of public school facilities (e.g., capacity, utilities, services, equipment, and facility condition). This is similar to the findings of Attfield and Vu (2013) for Vietnam where statistical analysis revealed that only nine out of 30 school facility variables were useful in modelling district level school performance.

Eight variables were evaluated as significant and were therefore selected for model development. For all variables, higher values are coded to be more favourable. The number of classrooms \( (Room_i) \) and buildings \( (Building_i) \) determine the size of school facility \( i \). The number of teachers in excess of the standard pupil-to-teacher ratio \( (ExcessTchr_i) \) and the toilet-to-pupil ratio \( (ToiletP_i) \) also give an indication for the capacity of school \( i \). The school services variable \( (Service_i) \) denotes the availability of a library, health clinic, or canteen in the school where more services result in a higher value. The type of available utilities \( (Utilities_i) \) specifically electricity, water, sewerage, and communication was constructed such that more and better utilities have higher scores (e.g. higher values for local piped water as opposed to water wells). Finally, school accessibility as measured by road conditions \( (Road_i) \) and proximity from the town centre \( (Proximity_i) \) is also significant and therefore considered in the analysis. T-test results of the selected variables indicate that the values of Proximity and ToiletP may exceed the computed standard error (see Table 7-1). The spatial distribution of the variables for the study area is given in Figure 7-2. Shades of red indicate higher values and shades of blue indicate lower values.

<table>
<thead>
<tr>
<th>Variable</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>5.38</td>
</tr>
</tbody>
</table>
To begin with, the whole study area (i.e., the cluster of eight provinces in the eastern seaboard) has more top performing school hotspots compared to the rest of the country (see Figure 7-1). In particular, the entire province of Southern Leyte (dark green polygon in Figure 7-1c) and Agusan del Norte (dark blue polygon in Figure 7-1c) is a hot spot of top performing schools (see Figure 7-2a). A possible explanation is the low risk for armed conflicts in these two provinces (Bautista, 2005). The majority of the top performing school hotspots in the study area are located around the city centres, but a few are located in rural areas, for example in Eastern Samar (light orange polygon in Figure 7-1c) and Surigao del Sur (red polygon in Figure 7-1c).

There are two types of patterns in the spatial variation of the variables as indicated in the hotspot maps. Figure 7-2a-e exhibit wide dispersions while Figure 7-2f-i exhibit tight clusters. Better toilet ratios are usually found among schools located outside the cities due to lower student populations (see Figure 7-2b) as school buildings are prevalent even in the sparsely-populated rural areas (see Figure 7-2c). Eastern Samar (shown in the light orange polygon in Figure 7-1c) and the western portion of Agusan del Sur have the worst provisions for services and basic utilities (see Figure 7-2d) which might be due to inaccessibility. Figure 7-2e indicates the hotspots of school services which are located in Bayugan, Butuan and Cabadbaran (these are cities in Agusan del Sur and Agusan del Norte – light blue and dark blue polygons in Figure 7-1c) as well as Tandag (a city in Surigao del Sur – red polygon in Figure 7-1c).

Higher values are clustered in the cities for the remaining variables. Room hotspots and excess teachers are only located in the larger cities (see Figure 7-2f-g). Moreover, schools in the cities are expected to be more accessible with better road conditions and proximity to the local town hall as shown in the hotspot maps (see Figure 7-2h and Figure 7-2i).
(a) Top performing schools ($TopSch_i$)  
(b) Toilet-to-pupil ratio ($ToiletP_i$)  
(c) School buildings ($Building_i$)  
(d) School utilities ($Utilities_i$)  
(e) School services ($Service_i$)  
(f) Classrooms ($Room_i$)  
(g) Excess teachers ($ExcessTchr_i$)  
(h) Road conditions ($Road_i$)  
(i) Proximity to the town centre ($Proximity_i$)

**Figure 7-2.** Spatial distribution of the variables
7.3 Regression Modelling

GWR is again utilized in this chapter for investigating spatially varying relationships. A geographically weighted logistic regression (GWLR) can be fitted for modelling binary outcomes with geographically varying coefficients. Nakaya et al. (2009) developed a semi-parametric extension to allow the mixing of geographically varying and fixed coefficients. In this chapter semi-parametric GWLR was utilized to determine whether the relationship between school facilities and the occurrence of top performing schools varied depending on location. A semiparametric GWLR model is described as:

\[ y_i \sim Bernoulli(p_i) \]  
Equation (7-2)

\[ \logit(p_i) = \sum_k \beta_k(u_i, v_i)x_{k,i} + \sum_l \gamma_lz_{l,i} \]

where \( y_i \) is the dependent variable, \( p_i \) is the modelled probability that the dependent variable becomes one, \((u_i, v_i)\) is the x-y coordinate of the \( i \)th location and the coefficients \( \beta_k(u_i, v_i) \) are varying conditional on the location. \( x_{k,i} \) is the \( k \)th independent variable and \( z_{l,i} \) is the \( l \)th independent variable with a fixed coefficient \( \gamma_l \).

As observed in Chapter 6, coefficient estimates, model diagnostics, and “golden search” bandwidth sizes can be automatically computed using GWR 4.0 (Nakaya et al., 2009). The golden section search function of the GW4R 4.0 tool was again used to compute for the bandwidth size. To estimate the geographical weights of local coefficients, this study utilized an adaptive bi-square kernel weighting formula (see Equation 7-3).

\[ w_{ij} = \begin{cases} 
\left(1 - \frac{d_{ij}^2}{\theta_{(k)}^2}\right)^2, & d_{ij} < \theta_{(k)} \\
0, & d_{ij} > \theta_{(k)} 
\end{cases} \]  
Equation (7-3)

where \( w_{ij} \) is the weight value of the observation at location \( j \) for estimating the coefficient at location \( i \), \( d_{ij} \) is the Euclidean distance between \( i \) and \( j \), and \( \theta_{(k)} \) is an adaptive bandwidth size defined as the \( k \)th nearest neighbour distance. Bi-square kernels
are suitable for clarifying local extents for model fitting due to its clear-cut range with non-zero kernel weights. The number of samples included in the kernel is kept constant in adaptive kernels so that use of bi-square kernels is secure (Nakaya, 2014).

The association between the dependent and independent variables is investigated by fitting a regression model. There is no multicollinearity among the independent variables but the global model (ordinary least squares) is biased and the residuals are spatially autocorrelated. This is an indication that local analysis may be useful. Fixed and spatially varying parameters for local analysis were identified by performing geographical variability tests for each of the independent variables. The model with the lowest AICc value was selected after comparing a series of models that estimated the weights of the local coefficients.

| Table 7-2. Comparison of regression model performance |
|-----------------|--------|--------|--------|
|                | OLS    | GWR    | S-GWR  |
| Model fit      | 0.08   | 0.18   | 0.18   |
| AICc           | 4412   | 4280   | 4181   |
| Bandwidth      | NA     | 431    | 315    |
| N              | 3481   | 3481   | 3481   |

As indicated in Table 7-2, using the entire data set (which spans around 20,000 km$^2$) to estimate the occurrence of top schools through OLS is ineffective. The low model fit indicates that the characteristics of the schools are too disparate to detect patterns when the full scope is considered. When the scope is decreased to 12% or 431 neighboring schools and the dependent variable is modeled using GWR, there is considerable improvement in the model fit. This indicates that the characteristics of neighboring schools are more comparable than schools that belong to non-neighboring provinces. However, the best model (i.e., lowest AICc) was semiparametric which combined fixed and spatially varying coefficients depending on the geographical coordinate of the location $u_i = (x_i, y_i)$. The 100-point improvement between the AICc values of the GWR and S-GWR models indicates that there is a considerable change in the model performance. Fixed and spatially varying parameters were identified by utilizing two techniques for each of the independent variables. First, geographical variability tests (which fit the same bandwidth in the compared models) has identified
the $\text{Intercept}_i$ as non-stationary (diff-criterion\textsuperscript{36} is -139.39) while the assessment of $\text{Room}_i$ as non-stationary was weak (diff-criterion is 0.11). In contrast, $\text{Service}_i$, $\text{Proximity}_i$, $\text{Road}_i$, $\text{ToiletP}_i$, and $\text{ExcessTchr}_i$ were assessed as stationary variables with diff-criterion values between 11 and 22. $\text{Building}_i$ and $\text{Utilities}_i$ were likewise assessed as stationary in this method (diff-criterion of 8.54 and 8.06 respectively) but the results of the second method indicate that $\text{Building}_i$ and $\text{Utilities}_i$ should be non-stationary. In the second method, the optimal bandwidth of each model was computed prior to model comparison tests in the “local to global” variable selection routine of GWR 4.0. In this technique, the model where $\text{Room}_i$, $\text{Building}_i$, $\text{Utilities}_i$ and $\text{Intercept}_i$ are spatially varying has the lowest AICc value and outperformed all the other models. Therefore based on the results of the two methods, the fixed variables are: $\text{Service}_i$, $\text{Proximity}_i$, $\text{Road}_i$, $\text{ToiletP}_i$, and $\text{ExcessTchr}_i$; while the spatially varying variables are: $\text{Room}_i$, $\text{Building}_i$, $\text{Utilities}_i$, and the $\text{Intercept}_i$. The best bandwidth size is 315 schools which covers approximately 9% of the study area. The model is given in Equation (7-4):

$$\text{TopSch}_i = \sum \alpha_0 (u_i) + \sum \alpha_1 (u_i) \text{Room}_i + \sum \alpha_2 (u_i) \text{Building}_i$$
$$+ \sum \alpha_3 (u_i) \text{Utilities}_i - 0.147 \text{Service}_i - 0.035 \text{Proximity}_i$$
$$+ 0.036 \text{Road}_i + 0.007 \text{ToiletP}_i + 0.203 \text{ExcessTchr}_i$$

Equation (7-4).

where the coefficient parameters $\alpha$ were estimated based on the data of 3,481 public elementary schools in the study area (the variables are as defined in the previous section). The coefficients of Equation (7-4) indicate that the occurrence of top schools increase by 0.203 for each teacher that is provided in excess of the recommended pupil-teacher ratio. The odds also increase by 0.036 when better roads are used to access the school. A slight increase of 0.007 is attributed to higher toilet-pupil ratios. However, the negative coefficients of $\text{Service}$ and $\text{Proximity}$ indicate that schools located near city centres lower their chances of becoming a top school despite having more school services. Meanwhile, the spatially-varying coefficients are mostly positive but a few

\textsuperscript{36} The diff of criterion value shows the difference between the original and switched GWR models by comparing the selected model indicators (in the case of this study, the AICc was the selected model indicator). Positive values indicate that the switched model has a better fit and the evaluated variable is stationary. Values between -2 and +2 indicate that there is no significant difference in performance between the original and switched models.
areas are negative as illustrated in Figure 7-4. Collinearity in the estimated coefficients is investigated as recommended by Wheeler (2014). Figure 7-3 shows the absence of collinearity in the spatially varying coefficients of Equation 7-4. Table 7-3 summarizes the standardized coefficients as it varies depending on the geographical coordinate of the school $u = (x_i, y_i)$. Figure 7-4a illustrates the spatial variation in the occurrence of top performing schools that is explained by the model. Coefficient estimates for locations with statistically significant t-values of the spatially varying parameters are illustrated in Figure 7-4b, Figure 7-4c, Figure 7-4d and Figure 7-4e. The mapping technique for presenting GWR results in this way is adapted from Matthews and Yang (2012). Shades of blue in the maps (Figure 7-4) indicate significant positive parameter estimates whereas shades of green indicate significant negative parameter estimates. Insignificant estimates (i.e., t-values between -1.96 and 1.96) are masked out and indicated as white areas.

**Figure 7-3.** Scatterplot matrix of estimated coefficients from the semiparametric GWLR model

**Table 7-3.** Summary statistics for varying local coefficients in Equation 7-4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min Quartile</th>
<th>Lwr Quartile</th>
<th>Median Quartile</th>
<th>Upr Quartile</th>
<th>Max Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.010</td>
<td>-0.354</td>
<td>0.007</td>
<td>0.512</td>
<td>1.864</td>
</tr>
<tr>
<td>Room</td>
<td>-0.797</td>
<td>0.231</td>
<td>0.501</td>
<td>0.869</td>
<td>3.677</td>
</tr>
<tr>
<td>Building</td>
<td>-0.389</td>
<td>0.105</td>
<td>0.311</td>
<td>0.589</td>
<td>1.979</td>
</tr>
<tr>
<td>Utilities</td>
<td>-0.378</td>
<td>0.088</td>
<td>0.219</td>
<td>0.434</td>
<td>1.196</td>
</tr>
</tbody>
</table>

Variable coefficients are standardized.
Figure 7-4. The spatial variation of the model fit and the spatially varying parameters with significant t-values in Equation 7-4. Parameter estimates are insignificant in the white areas.

The semiparametric model suggests that the relationship between the occurrence of top performing schools, services, proximity to town centres, road conditions, toilet ratios, and excess teachers is stationary over space. However, the strength of the relationship between top performing public elementary schools and rooms, buildings, and utilities varied over the study region. In Figure 7-4a, low model fit estimates in urbanized areas suggest that the model fails to account adequately for variations in top performing schools among these highly-populated districts. This result suggests that the influence on academic performance of school facility aspects examined in this research is not significant in city centres. Instead, it seems to be more influential among inaccessible and sparsely-populated rural areas. In semiparametric GWLR, the pseudo-$R^2$ is the likelihood ratio $R^2$. It is a measure of the local goodness of fit or the local percent deviance explained by the model and is defined as:
where \( dev_i \) is the locally weighted deviance of the fitted model and \( nulldev_i \) is the locally weighted deviance of the null model having only a constant term at location \( i \). Higher values denote better model fit. Lower values indicate that there is a large variance between the predicted and expected values at location \( i \).

Semiparametric GWLR modelling indicates that the effect of better road conditions, better toilet ratios and excess teachers on the occurrence of top performing schools did not significantly vary across the study space and were generally comparable across all locations. Services and proximity, which was also not significantly varying, generally gave a negative effect on top performing schools in the study area.

### 7.4 Providing for Utilities and Sanitary Facilities in Public Schools

In the aim to investigate whether there is spatial variation in the relationship between school facilities and the occurrence of top performing schools, semi-parametric GWLR was employed to georeferenced school facility data. The study area is a cluster of eight provinces located in the eastern seaboard of the Philippines. The hypothesis is that the effect of basic school facilities on academic performance would vary depending on the social and economic infrastructure within the locality.

#### Stationary Variables

**Teachers:** The results indicate that the provision of as little as one to three teachers in excess of the recommended 1:35 teacher-to-pupil ratio of the country has a positive effect regardless of location or local context. This is consistent with the findings of other papers where teachers have a significant “within school” effect on student performance (Rivkin et al., 2005; Glewwe et al., 2011).

**Toilets:** More toilet facilities were also significantly associated with the top performing schools regardless of location, although the influence is small as in Jasper et al. (2012), Adukia (2013), and Garn et al. (2014). Water, sanitation, and hygiene (WASH) is a key public health issue in many poor countries and is essential for the survival and development of children (UNICEF, 2014). A review of the literature
indicates that most investigations correlate a school’s sanitary facilities with either increased attendance or better health conditions (Bartlett, 2003; Burton, 2013). The small effect of sanitary facilities will be rendered insignificant if combined with socio-economic variables (being strong predictors of academic achievement).

**Road Conditions**: Better road conditions are associated with the top performing schools. The significant impact of improved road conditions on the education outcomes of poor rural communities are depicted in other papers as well, such as Levy (2004) and Mu and Van de Walle (2007). They cited the following reasons as the likely cause: (a) absenteeism among students and teachers dropped; (b) enrolment doubled; and (c) improved accessibility allowed the recruitment of more teachers and staff.

**Proximity**: The negative coefficient for proximity denotes that top performing schools are usually located far from the local town halls. The schools are usually located at a distance of 2-8 km from the town centres, as shown in Figure 4-2.

**Services**: The negative coefficient for services in the SGWR model may be attributed to the fact that the provision of services is not enough to ensure better student performance. The custodians and users of these facilities should also be provided with the skills so they can use and maximize the available resources. The low impact in the provision of services (e.g., school health clinics, libraries and canteens) to academic performance can also be due to the lack of support from politicians to fund manpower and continuously provide amenities which are necessary to maximize the resource. For example, due to limited funds in developing countries, an existing health clinic can still lack the necessary preventive health resources and skilled workers to run the facility effectively. Similarly, it is rare for a school library among poorer schools to contain an updated collection of learning materials. Poorer communities do not have the necessary funds to manage these facilities, and external assistance (either through government or private agencies) is deficient because there is a low incentive for the providers to make the service available. Batley and McLoughlin (2015) described how public services such as school health clinics that provide vaccinations and health campaigns benefit the community as a whole and not the users directly. For example, vaccine-preventable diseases will only be purged when the whole community is vaccinated; polluted and contaminated surroundings can only be eliminated when the whole community participates in proper waste disposal. Since the providers are unable to claim that a successful outcome is due to their efforts (e.g., a healthy and clean environment can be caused by several factors), Batley and McLoughlin (2015) concluded that there is no
political salience in these types of public goods which explains the lack of support from political leaders to provide the service.

**Non-stationary Variables**

The SGWR results show that among the facility variables used in this study, buildings, classrooms and utilities vary significantly over the study space regarding its relationship to the occurrence of top performing schools.

**Buildings:** The association between top performing schools and buildings are strongest in the north of Eastern Samar (light orange polygon in Figure 7-1c) even though this province is prone to natural calamities and armed conflict. It appears that schools in this vulnerable area provide children with relatively safe places to play within (Venton and Venton, 2012; Vickery, 1982). Further study is needed to understand why the high occurrence of top performing schools within this area is linked to schools that have more buildings while in the other areas the high occurrence of top performing schools is more evenly distributed across all building quantities.

The prevalence of school buildings in the sparsely-populated rural regions of the study area (see the building hotspot map on Figure 7-2c) is the result of a government effort in 2001 to solve inequality in education access by building one primary school for every barangay\(^{37}\), regardless of the considerations for population. As mentioned in Section 4.3, this project may have provided too many schools in the aim to solve the problem of school quantity. But the extensive use of school buildings requires consistent maintenance which is unfortunately obscured from the public view than the construction of physical buildings, thereby politicians may not be eager to prioritize it (Batley and McLoughlin, 2015). Future structural repairs in these extra facilities are recurrent expenditures that small schools cannot subsidize too. Therefore in the case of about 10% of public schools in the Philippines, the school facilities that were merely erected for political reasons were later reported as underutilized rooms and dilapidated buildings.

**Rooms:** Since rooms are contained within buildings, it might be expected that room hotspots would be similar to the building hotspots. However, this was not detected in the study area as room hotspots were only seen in city centres. A possible explanation might be that standard classrooms entail the provision of furniture (e.g., seats, tables,

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\(^{37}\) A barangay is the smallest administrative division, the local term for a village
electric fans, etc.) and other amenities necessary for student instruction, which require additional financial resources that small rural schools cannot support. Furthermore, these amenities are public goods with low visibility that tend to be less prioritized by elected officials especially in democratic governments (Batley and McLoughlin, 2015). Further study is needed to understand why associations between classrooms and top performing schools are stronger in rural parts of Leyte (light green polygon in Figure 7-1c) than in other locations within the study area.

**Utilities:** The provision of utilities is lowest in the province of Eastern Samar (light orange polygon in Figure 7-1c) than in any of the other provinces in the study area (see Figure 7-2d). Since public school facilities normally reflect the socioeconomic conditions of the municipality, it can be assumed that local households of Eastern Samar are also experiencing a deficiency in basic utilities. A possible explanation to the link between the high occurrence of top performing schools and the provision of more buildings and better utilities in this area is that children might have better academic performance if they are able to gain access to these basic amenities which are lacking at their home. Government reports indicate a timely intervention that education resource projects for the year 2016 will focus on the provision and improvement of water and sanitation facilities (UNESCO 2015 report).

The low provision of utilities and insignificant effect of school buildings in the western areas of Agusan del Sur (light blue polygon in Figure 7-1c) suggests that municipal funding to construct school buildings might have been put to better use if it was devoted to the provision of school utilities and toilets instead. This does not apply for all locations and the correlation cannot be generalized because the situation in each district is unique. For example in the rural northern areas of Eastern Samar (light orange polygon in Figure 7-1c), both buildings and utilities have significant positive contributions so it cannot be concluded that buildings will be a waste of resources and should be dropped in favour of utilities. Hence the best solution will depend on the context of each district.

Based on the spatial variation of the Intercept, it is clear that the increased performance of the model in selected areas is due to some other variables not included in the model. Considering all things equal, top performing schools were fewer than expected in urban locations as indicated by the insignificant and low values of the intercept in these areas. This was especially prominent in Tacloban (city in Leyte – light green polygon in Figure 7-1c), Bayugan (city in Agusan del Sur – light blue polygon in
Figure 7-1c) and Bislig (city in Surigao del Sur – red polygon in Figure 7-1c). However, there is a raised occurrence of top performing schools in the west of Ormoc (also a city of Leyte) and the north of Butuan (this is a city in Agusan del Norte – dark blue polygon in Figure 7-1c). The occurrence might be explained by the fact that these cities are the education centres in their respective regional administrations.

### The Effect of Local Context on Academic Achievement

The unusual high number of top performing schools (indicated by shades of blue in Figure 7-4b) was generally found within rural areas, for example, in the north of Eastern Samar (light orange polygon in Figure 7-1c), the south of Leyte, the rural areas of Southern Leyte (dark green polygon in Figure 7-1c), and the north of Dinagat Islands (a group of islands in Surigao del Norte – pink polygon in Figure 7-1c). Incidentally, most of these locations usually had universities nearby.

Unusually low occurrence of top performing schools (indicated by shades of green in Figure 7-3b) was also observed in rural areas, for example in Biliran (orange polygon in Figure 7-1c) and the north of Leyte. This might be attributed to the lower income levels of the municipalities in these areas. The correlation between income and achievement is not universal in the study area as there are also low income municipalities in the high-performing north of Eastern Samar and high income municipalities in the low-performing west of Agusan del Sur. Income is not always a sufficient indicator of achievement as provincial income levels do not reflect the challenges faced by the people, which can, in turn, affect the academic performance of children. For example, even with the high income generated by Agusan del Sur, there is a remarkably low occurrence of top performing schools in the province’s south that might be caused by armed conflict and health problems. Bautista (2005) found that increased armed conflict is experienced by communities in the area. To make matters worse, this province has the highest prevalence rate of intestinal helminth infections that primarily affects school age children due to the nature of agricultural work and inadequate sanitation in the locality (Belizario et al., 2013).

Semiparametric GWLR has confirmed that the effect of school facilities on academic performance varies depending on location by evaluating and allowing the mixing of geographically varying and fixed coefficients. Through this method the study

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38 As of 2010, Agusan del Sur is a 1st class province of the Philippines generating an annual revenue of more than PhP 450 million.
was able to gain new insights as to the possible mediating contribution of social and economic infrastructure around the school which might also be affecting the relationship between school facilities and academic achievement. The study has revealed that buildings, classrooms, and utilities have stronger positive effects in selected rural conditions than in urbanized areas. In general, sparsely populated rural areas (i.e., fewer classrooms) with poor road conditions experience the most benefit from better school facilities. This is in line with the findings of Husén (1990) that school facilities will have a significant contribution to education outcomes only up to a certain threshold of resources.

In an effort to understand how each aspect of the school facility affects academic performance, this study focused solely on school and teacher variables. Similar to Chapter 6, it purposely omitted family characteristics as the effect of school facilities becomes insignificant when prior estimates that involved aggregated municipal level socioeconomic census data of the study area are included in the regression models. The results of this research should be considered in light of the fact that facilities make very small impacts compared to family characteristics as demonstrated by the research of Hanushek and Luque (2003).
Chapter 8
Concluding Remarks and Future Work

The study was conducted to understand the relationship between education outcomes and school facilities in the context of developing countries, specifically the Philippines. It has identified aspects of the school facility that influence academic achievement in the Philippines and how local context contributes to the relationship. This topic is understudied within the framework of spatial analysis. Further investigation on the spatial variation of the relationship can aid education resource allocation especially for the changing education system of the Philippines.

This chapter begins with a summary of the main findings of the thesis and is followed by a discussion of its implications for government policy in terms of education resource monitoring and evaluation. It concludes with a discussion of the research limitations followed by an emphasis of significant contributions and an outline of topics for further study.

8.1 Empirical findings

The main empirical findings are chapter specific and were summarized within the respective chapters: spatial analysis of the disparities in education facilities, modelling the effect of deprived physical urban environments on academic performance in the Philippines, and investigating the relationship between school facilities and academic achievement through geographically weighted logistic regression. This section will synthesize the empirical findings to answer this study’s five research questions posed in Section 1.1.

(1) What are the factors that have affected the allocation of education resources in the Philippines?
A review of the policies that influence the allocation of education resources in the Philippines reveal that population is the main consideration for the construction and maintenance of school facilities. Large urban schools receive more funding than small rural schools because district budgets are hinged on the size of the student population. There is generally no site suitability assessment preceding building construction as most schools are built on donated lots. Schools are constructed even on unsuitable sites if there are enough students to populate each grade level. Analysis of the government-provided school facility data reveals that a typical public school in the Philippines has six classrooms contained within four single-level buildings. Shared (male and female) toilet facilities are common except in the capital and pupil-to-toilet ratios are alarming throughout the country. Despite a peak in school building construction in 1995, the majority (62%) of school buildings are currently in need of repair and around 10% are without basic utilities (e.g., water, sewerage, electricity, and communication facilities). During the year 2006, destructive natural calamities damaged 32% of the public schools around the country and resulted in a spike on school damage reports.

(2) How useful are spatial analysis techniques in the examination of school facilities?

It is only natural to study the topic of education outcomes and education resources through the lens of spatial analysis since education papers agree that both are influenced by the social environment. However, spatial analysis is not widely used in this area and the spatial factors affecting education are not commonly explored, especially in the examination of the relationship between academic performance and school facilities. The results of this thesis indicate that spatial analysis techniques are useful not only in identifying spatial factors that affect school facilities, but also in detecting local variations that are unseen by other methods utilized to analyse the association between academic performance and the built environment.

(3) Which aspect of the education facility affects education outcomes and deserves further examination with a spatial model?

Through spatial analysis and regression modelling techniques implemented within a GIS, this study was able to identify that, in the context of the capital as represented by the case study in Quezon City, proximity to poverty hotspots, the number of teachers
and classrooms, the building conditions and the availability of a school health clinic are important factors. In the context of schools located far from the capital as represented by the case study in the provinces located on the eastern seaboard, proximity to the town centre, road conditions, the number of teachers, toilets, classrooms and buildings, the available utilities and services were found to influence academic performance more than the other aspects of the school facility. Aside from the pupil-to-toilet ratio, all other shared equipment (e.g., seats, lighting, ventilation) did not have a strong effect. The weakness of library which was identified as a strong variable in other school facility studies is perhaps due to the homogeneity of the data.

(4) How could the spatial model help stakeholders prioritize aspects of the school facility for improvement given the local context?

Through cluster analysis and regionalization techniques, this study was able to identify four clusters of provinces with distinctly varying building conditions. School buildings in the country’s eastern seaboard (which is exposed to the Pacific Ocean and prone to natural disasters) are poor, compared to the buildings in relatively safe areas (e.g. northern provinces which are protected by a mountain range). Decades of civil unrest have also resulted in deteriorated education facilities in southern provinces. Schools located in and around the capital are exceedingly overcrowded. Increasing resources can alleviate disparities in all clusters except the capital.

Through GWR, the spatial model developed in this study was able to identify the effect of the capital’s deprived and overcrowded physical urban environments on academic achievement. Despite overcrowding, better building conditions are evident in these schools. Results indicate that school facility size is a stronger predictor of academic performance than neighbourhood characteristics. That is, schools with smaller pupil-teacher ratios can improve math scores even if they are located near disadvantaged communities. Public elementary schools located in deprived physical urban environments are able to provide better support if it attends to the health of the pupils through the provision of school health clinics.

In other areas beyond the capital, the effect of school facilities varies depending on the social and environmental conditions of each province. For example, the provision of basic utilities such as electricity, water, sewerage and communication in a school will have a stronger effect for children living in remote districts where these provisions are
scarce than in relatively urbanized areas where these amenities are more common. Utilizing a GIS-based regression method provided a clearer understanding of the situation as it demonstrated how the academic performance was affected by selected aspects of the school building and how this effect varied across each district. In the context of the eastern seaboard of the country, it is important for the government to increase education resource funds with regard to three aspects that result in better academic performance within the study area regardless of local situation: more teachers, the provision of better road conditions, and more toilets. The first aspect relates to the main aim of public education, which is to instruct the population. The second aspect indicates that districts lacking appropriate transportation infrastructure are deprived of the means to engage in not only business but also academic activities. Lack of transportation infrastructure might be restricting the government from providing other essential services such as tap water, electricity, sanitation, and suitable school facilities. The same might also be restricting the continuous school attendance of children. The third aspect relates to the provision of sanitary facilities which are essential for children as they spend more than four hours in school.

Overall, this study was able to identify aspects of the school facility that should be prioritized given the social and environmental conditions of a district. It was able to provide evidence to policymakers that school facilities and education outcomes are also affected by local conditions such as geography and the socioeconomic conditions of neighbouring provinces.

(5) How reliable, sensitive, valid and useful is the proposed spatial model in education resource monitoring and evaluation?

School facilities are essential elements of the education system and financial resources are required to build and maintain them. For this reason, even though school effects are considered very small in comparison to family characteristics, the thesis aims to understand how they affect academic achievement. The results of this study indicates that school facilities in the Philippines seem to be more influential among schools that serve students who are deprived of access to suitable basic government utilities (e.g., water and electricity) and services (e.g., transportation and health) such as those living within informal settlements in the city or within inaccessible and sparsely-populated rural areas.
Spatial statistics and regression models illustrate the non-stationarity of the association between academic performance and the built environment within Quezon City, Philippines. The application of OLS and GWR only estimated up to 23% of the variation in math scores but S-GWR was able to estimate as much as 30%. S-GWR provided better estimates than OLS or GWR methods by fixing the variables that pertain to school facilities such as classrooms, teachers, and building conditions while allowing the other variables such as informal settler locations and clinics to vary spatially. S-GWR was also able to detect weak spatial variation that favoured wealthier areas in the provision of school clinics among the city’s public schools. The model performs better in the northern part of the study area where larger informal settlement communities are located.

The influence of school facilities on academic performance is more significant in rural areas compared to city centres, even among urbanized areas far from the capital in a developing country such as the Philippines. Among schools located in the eastern seaboard provinces, results of the logistic form of S-GWR indicate that the effect of better road conditions, better toilet ratios and excess teachers on the occurrence of top performing schools did not significantly vary whether the school was located in rural or urbanized districts. Services and proximity generally gave a negative effect on the incidence of top performing schools, meaning that the current characteristics of schools near the town centres are not conducive to learning and that the provision of services (e.g., libraries, health clinics, canteens) are not enough to improve academic performance. However, the effect of basic utilities (e.g., water, sanitation, electricity, communication) and facility size (e.g., the number of classrooms and buildings) varied spatially depending on the local conditions affecting the school and the community. For example, the provision of basic utilities such as electricity, water, sewerage and communication in a school will have a stronger effect for children living in remote districts where these provisions are scarce than in urban areas where these amenities are common. Utilizing a semiparametric GWR method provided a clearer understanding of the situation as it demonstrated how the academic performance was affected by selected aspects of the school building and how this effect varied across each district. The model estimated up to 36% of the occurrence of top performing schools within selected rural areas.
8.2 Implications for Theory and Policy

Since geographic and social factors beyond the control of the local school boards affected the physical condition of the school buildings, the national government has to address these issues in order to minimize the disparities and provide equal access to education. The proposed reallocation of education resources that is relative to the current state of a province is shown to mitigate the situation by eliminating disparities caused by the natural and social environment but not the ones caused by overpopulation. The results of this study indicate that the government should invest more resources in the maintenance and upgrade of school buildings that are prone to degradation caused by environmental calamities or disordered communities in order to reduce the disparity between provinces.

The results of this study show that school building quality in the Philippines is affected by geography, climate, and societal conditions. The findings contribute to the understanding of education resource allocation in the Philippines in terms of geographic distribution as well as the disparities in education facilities between clusters of provinces. It is evident that geography, climate, and societal conditions should be included in models depicting the relationship between school physical environment and student outcomes as those proposed by Cash (1993) and Tan et al. (1997). This finding is crucial for the Philippine government as it attempts to channel inadequate financial resources into projects that will have the greatest impact on education outcomes.

Since bigger schools were shown to have better outcomes and are preferred by students, it is recommended that school quality be prioritized in the context of urban poor communities. This supports the recommendation of Hanushek (1995) and Kremer (1995) that school quality should be prioritized over school quantity. This study has also shown that the provision of health care support and smaller pupil-teacher ratios are needed for academic achievement in the context of schools serving urban poor families in Quezon City, Philippines. Ensuring the provision of clinics as well as maintaining few large schools with small pupil-teacher ratios may be more cost effective for the government but challenging to manage and logistically implement for the administrators. Programs that target increasing the academic performance of children from informal settler communities should prioritize these aspects in the face of inadequate resources of developing countries such as the Philippines.
Better utilities matter only for areas that lack this service. The provision of more rooms and buildings should only be prioritized for selected areas because, like utilities, the effect of this resource will vary. Proximity of the school to the town centre is not important as the crowded facilities reduce the academic performance of young children. Finally, since the provision of services is also correlated with town centres in general, they had a negative effect because the general lack of financial resources to sustain and support the effective utilization of the service renders it useless.

Finally, this study has shown that there is no standard one-size-fits-all solution in terms of education resource allocation because the effectiveness of school provisions will vary depending on the context of the school community. This supports the recommendations of Glewwe et al. (2011) for customized solutions in terms of education resource allocation. The findings are useful in the context of decentralized planning as it can identify which education resource should be prioritized by each district in order to improve academic performance. Recognizing the best solution for the context of the people is essential if the provision of resources has to be prioritized due to financial limitations.

8.3 Recommendations

Allowing selected school resource variables to vary spatially as in S-GWR was able to provide better estimates than traditional fixed coefficients as in OLS or allowing all variables to vary spatially as in GWR. The results stem from the fact that there is regional disparity in the country. As stated in Section 2.3, the country’s diverse geography affects economic activities as well as the establishment of cities and public infrastructure such as roads and utilities. This spatial variation in economic development has also affected the provision of school resources. Based on the results of this thesis, each locality requires customized planning to identify local needs that should be addressed in order to achieve better academic performance. The following actions are proposed for the DepEd and the local governments of the Philippines:

1. Since the natural and social environment affects school buildings, these factors should be considered in the planning and maintenance of school facilities. For
example, schools that are prone to natural calamity and civil conflict should be given more financial resources to maintain their facilities.

2. Schools serving relatively poorer communities should monitor the provision of government services and utilities because these amenities have a larger effect on education outcomes for children who are unable to access these resources. For example, the provision of school health clinics should be improved in public elementary schools of Quezon City while better roads, the availability of water supply, and electric power are more important in the context of public elementary schools in the eastern seaboard. Since schools are the focal point for local communities, it can be a venue for citizens to organize and advocate for better services.

3. The provision of adequate pupil ratios for school toilets should be improved. Data shows that there is an alarming shortage of school toilets across the country, especially among public elementary schools in the capital.

4. Across the country, there is a distinct drop in academic performance among schools located in urbanized areas. A possible cause is the larger class sizes in these bigger schools, among other things. Therefore in the aim to improve academic performance, the provision of better pupil-teacher ratios is recommended.

8.4 Future Studies

Future studies can look into the effects of school sanitation facilities on education outcomes as well as its effects on the local community’s health. It will be interesting to find out whether the alarming need for public school facilities across the country will be solved in due time by the recent increase in the government’s education budget. Nevertheless, it is acknowledged that an increase in funding does not always solve the problem because non-financial factors may also affect the allocation of education resources as the ability to utilize assets is crucial to solve disparities in decentralized education systems.

Further study is needed to understand how visualizing the effect of the social and environmental context on education outcomes can help justify customized financial allocations and priorities for school facilities. Since knowledge of the local context is
important, utilizing participatory mapping methods as a means to disseminate information and gather feedback from the community can also be explored in the aim to facilitate transparency in the management of public resources. Future work on public participation geographic information system (PPGIS) in the context of education resource monitoring and evaluation (for example, visualizing the strength of connections between schools through proximity, transportation networks, social networks, or other resource-sharing means) is also needed as it was suggested by Hite (2008) as a possible means to identify the roles and goals as well as resolve tensions between (central and regional) participants in a decentralized education system.

8.5 Concluding remarks

Most education studies have shown that societal conditions of family characteristics play a large part in predicting academic performance. According to Husén (1990), however, this does not mean that schools cannot make a difference. On the contrary, schools should ensure that the right resources are provided so that already disadvantaged students will be equipped to catch up. This study has shown that there is no standard one-size-fits-all solution because the provisions will vary depending on the context of the school community. However, the findings are useful for decentralized planning as it can identify which education resource should be prioritized by each district in order to improve academic performance. Recognizing the best solution for the context of the people is essential if the provision of resources has to be prioritized due to financial limitations. The analysis of school facilities serves as a guide for identifying government interventions (e.g., transportation, sanitary facilities) which can improve community conditions and eventually enhance education outcomes.

Primary education outcomes for the poor in terms of completion and learning achievement depend crucially upon government policy for ensuring that adequate resources are provided for those critical inputs identified by production function studies. In a decentralized management of school resources, the unique situation of each school district should be recognized.


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HOUSING AND URBAN DEVELOPMENT COORDINATING COUNCIL 2014. Developing a national informal settlements upgrading strategy for the Philippines (Appendix I : comprehensive assessment report), Philippines, HUDCC.


ROTHSTEIN, R. 2013. Why children from lower socioeconomic classes, on average, have lower academic achievement than middle class children. Closing the opportunity gap: What America must do to give every child an even chance, 61-74.


Appendix A

Figure A-1. Enlarged version (northern part) of map presented in Figure 4-3.
Figure A-2. Enlarged version (southern part) of map presented in Figure 4-3.
Figure A-3. Condition of school buildings as reported by 75.8% of public schools in the Philippines (building condition, number of schools)

Figure A-4. Dangerous objects in school sites with legal issues as reported by 2% of public schools in the Philippines
Figure A-5. Number of buildings per school

Figure A-6. Number of levels per building (number of building records, percent of total building records)
Figure A-7. Number of classrooms per school

Figure A-8. Number of toilets per province as reported by 63.8% of public schools with values in both enrolments and toilets.
Figure A-9. Water sources as reported by 7.8% of public schools in the Philippines (number of schools, percent of reporting schools)

Figure A-10. Sewerage facilities as reported by 7.8% of public schools in the Philippines (number of schools, percent of reporting schools)
Figure A-11. Sources of electricity as reported by 7.8% of public schools in the Philippines (number of schools, percent of reporting schools)

Figure A-12. Communications facilities as reported by 7.8% of public schools in the Philippines (number of schools, percent of reporting schools)
### Table B-1. School facility data aggregated by province

<table>
<thead>
<tr>
<th>Administrative Divisions</th>
<th>Frequency Distribution of Variables</th>
<th>Provincial Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>% of Schools with Data on</td>
<td>Total Students</td>
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<td>Building Conditions</td>
<td>Classrooms</td>
</tr>
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<td>Province</td>
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<tr>
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<td>Pangasinan</td>
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</tr>
<tr>
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<td>41 Antique</td>
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<td>48 Negros Oriental</td>
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<tr>
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<td>49 Siquijor</td>
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<td>Eastern Visayas</td>
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<td>(Region VIII)</td>
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<td>59 Bukidnon</td>
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<td>61 Lanao del Norte</td>
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<td>62 Misamis Occidental</td>
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<td>Region</td>
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<td>% of Schools with Data on Building Conditions</td>
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<td>Classrooms</td>
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<tr>
<td>Davao Region</td>
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<td>Misamis Oriental</td>
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