การใช้แบบจำลองเชิงพื้นที่เพื่อกำหนดที่ตั้งและพื้นที่บริการที่เหมาะสมของโรงเรียนในเขตพื้นที่การศึกษา 2 จังหวัดนครปฐม ประเทศไทย

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SPATIAL MODELLING FOR OPTIMAL LOCATIONS AND ALLOCATIONS OF SCHOOLS IN EDUCATIONAL SERVICE AREA OFFICE 2 NAKHON PATHOM PROVINCE THAILAND

Sirirat Phongpipattanapan

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Geoinformatics

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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Thesis Examining Committee

(Asst. Prof. Dr. Sunya Sarapirome)
Chairperson

(Asst. Prof. Dr. Songkot Dasananda)
Member (Thesis Advisor)

(Asst. Prof. Dr. Suwit Ongsomwang)
Member

(Assoc. Prof. Dr. Sura Pattanakiat)
Member

(Dr. Dusdi Chanlikit)
Member

(Dr. Somkid Phumkokrux)
Member

(Prof. Dr. Sukit Limpijumnong)
Vice Rector for Academic Affairs

(Assoc. Prof. Dr. Prapun Manyum)
Dean of Institute of Science

มหาวิทยาลัยเทคโนโลยีสุรนารี

สิริรัตน์ พงศ์พิพัฒนพันธุ์ : การใช้แบบจำลองเชิงพื้นที่เพื่อกำหนดที่ตั้งและพื้นที่บริการที่เหมาะสมของโรงเรียนในเขตพื้นที่การศึกษา 2 จังหวัดนครปฐม ประเทศไทย (SPATIAL MODELLING FOR OPTIMAL LOCATIONS AND ALLOCATIONS OF SCHOOLS IN EDUCATIONAL SERVICE AREA OFFICE 2 NAKHON PATHOM PROVINCE THAILAND) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.ทรงกต ทศานนท์, 218 หน้า.

วัตถุประสงค์หลักของวิทยานิพนธ์ฉบับนี้ คือการสร้างแผนที่ตำแหน่งที่ตั้งโรงเรียนที่เหมาะสมภายใต้เงื่อนไขกำกับที่กำหนด และการประเมินประสิทธิภาพของแผนที่โรงเรียนที่ได้รับดังกล่าวในแง่ของเขตพื้นที่ให้บริการ ภาระการให้บริการ และระยะเดินทางสู่โรงเรียนของนักเรียนการศึกษาครอบคลุมโรงเรียนพื้นฐาน 3 ระดับคือ ระดับประถมศึกษา มัธยมศึกษาตอนต้น และมัธยมศึกษาตอนปลาย

ผลจากการศึกษาพบว่าในระดับประถมศึกษา โรงเรียนปัจจุบันมีประสิทธิภาพดีที่สุดในแง่ของจำนวนพื้นที่นอกเขตบริการ (เนื่องจากการมีจำนวนโรงเรียนที่สูงกว่ามาก) ในขณะที่ผลจากแบบจำลองเชิงอุดมคติและแบบจำลอง p-median ให้ผลดีใกล้เคียงกัน อย่างไรก็ตามในแง่ของพื้นที่บริการทับซ้อน แบบจำลองเชิงอุดมคติทำได้ดีที่สุด (โดยเฉพาะในระยะทางบริการ 1-3 กิโลเมตร) และระบบโรงเรียนปัจจุบันทำได้ดีน้อยสุด สำหรับระดับมัธยมศึกษาตอนต้น แบบจำลองเชิงอุดมคติทำได้ดีที่สุดในแง่ของจำนวนพื้นที่นอกเขตให้บริการ ขณะที่ระบบโรงเรียนปัจจุบันและผลจากแบบจำลอง p-median ทำได้ดีใกล้เคียงกัน แต่ในแง่ของพื้นที่ทับซ้อน ระบบโรงเรียนปัจจุบันทำได้ดีที่สุดที่ระยะบริการ 3 กิโลเมตร และแบบจำลอง p-median ทำได้ดีน้อยที่สุด อย่างไรก็ตามที่ระยะบริการ 5 และ 7 กิโลเมตร แบบจำลอง p-median ทำได้ดีที่สุด ขณะที่แบบจำลองเชิงอุดมคติทำได้ดีน้อยที่สุด แม้มีจำนวนโรงเรียนเท่ากัน (50) ในระดับมัธยมศึกษาตอนปลาย ผลจากแบบจำลอง p-median ทำได้ดีที่สุดในแง่ของจำนวนพื้นที่นอกเขตบริการ โดยมีผลที่ได้จากแบบจำลองเชิงอุดมคติทำได้ดีรองลงไป แต่ในแง่ของพื้นที่บริการทับซ้อนแบบจำลอง p-median ทำได้ดีที่สุดที่ระยะบริการ 5 กิโลเมตร แต่ที่ระยะบริการ 7 และ 10 กิโลเมตร ระบบโรงเรียนปัจจุบันทำได้ดีที่สุด

ในแง่ของภาระบริการระดับประถมศึกษาแบบจำลองเชิงอุดมคติทำได้ดีที่สุด โดยมีแบบจำลอง p-median ทำได้ดีรองลงมา และระบบโรงเรียนปัจจุบันทำได้ดีต่ำสุด สำหรับระดับมัธยมศึกษาตอนต้นและตอนปลาย แบบจำลอง p-median ทำได้ดีที่สุด และระบบโรงเรียนปัจจุบันทำได้ต่ำสุด ในแง่ระยะเดินทางระดับประถมศึกษา ระบบโรงเรียนปัจจุบันทำได้ดีที่สุด (ที่ 1.62 กิโลเมตร) เนื่องมาจากการมีจำนวนโรงเรียนที่สูง (127) ขณะที่แบบจำลอง p-median และแบบจำลองเชิงอุดมคติทำได้ดีรองลงมา (ที่ 1.97 และ 2.46 กิโลเมตร) ในทางตรงข้ามที่ระดับ

มัธยมศึกษาตอนต้น แบบจำลอง p-median ทำได้ดีที่สุด ตามด้วยแบบจำลองเชิงอุดมคติและโรงเรียนปัจจุบัน ตามลำดับ (2.01/2.4/2.66 กิโลเมตร) สำหรับระดับมัธยมศึกษาตอนปลาย แบบจำลอง p-median ทำได้ดีที่สุด ตามด้วยแบบจำลองเชิงอุดมคติ และระบบโรงเรียนในปัจจุบัน ตามลำดับ (2.91/4.19/4.80 กิโลเมตร)

นอกจากนั้นผลการศึกษาพบว่า แผนที่โรงเรียนที่จัดทำสำหรับ ค.ศ. 2015 และ 2020 ไม่ปรากฏความแตกต่างไปจากกันมากนัก (และไม่แตกต่างมากนักกับแผนที่สำหรับ ค.ศ. 2007 ด้วย) ส่งผลทำให้ประสิทธิภาพของแผนที่โรงเรียนที่ประเมินได้ มีความสอดคล้องกันไปด้วยทั้งในแง่ของเขตบริการและระยะเดินทางในทุกระดับของโรงเรียน

มหาวิทยาลัยเทคโนโลยีสุรนารี

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา Sirirat P.

ปีการศึกษา 2553 ลายมือชื่ออาจารย์ที่ปรึกษา S. Dasanamoda

SIRIRAT PHONGPIPATTANAPAN : SPATIAL MODELLING FOR OPTIMAL LOCATIONS AND ALLOCATIONS OF SCHOOLS IN EDUCATIONAL SERVICE AREA OFFICE 2 NAKHON PATHOM PROVINCE THAILAND. THESIS ADVISOR : ASST. PROF. SONGKOT DASANANDA, Ph.D. 218 PP.

SCHOOL MAPPING/ SCHOOL SERVICE AREA/ SCHOOL SERVICE LOADING/ P-MEDIAN/ GRAVITY P-MEDIAN

Main objectives of the thesis are to construct proper school location maps under some prescribed criteria and to assess efficiencies of these obtained school maps in terms of service area, service loading, and travel distance to school of students. Threeschool levels were studied: primary (P), lower secondary (LS), and upper-secondary (US).

It was found that, at P-level, present situation did best in term of no-service area (due to much higher number of schools), while the idealized and p-median scenarios did comparably well. However, in term of the overlapped area, the idealized scenario did best (especially at 1-3 km distance limits) and the present scenario did worst. At LS level, the idealized scenario did best in term of no-service area (due to lower number of schools) while present and p-median scenarios did comparably well. The overlapped area, present situation did best at 3 km limit and the p-median did worst. At 5 and 7 km limits, the p-median did best while the idealized did worst though they have the same amount of functioning schools at this level (50). At US-level, p-median scenario did best in term of no-service area followed by idealized

scenarios. But in term of overlapped area, the p-median did best at 5 km limit but at 7 km and 10 km limits, the present situation did best.

In term of the service loading, at P level, idealized did best followed by p-median scenarios while the present scenario did worst. At LS and US levels, the p-median did best while present scenario did worst.

In term of the travel distance, at P level, present scenario did best (at 1.62 km) due to high number of school (127). This is followed by the p-median and idealized methods (at 1.97 and 2.46 km). On the contrary, at LS level, the p-median did best followed by the idealized and present scenarios (2.01/2.4/2.66 km). At US level, the p-median also did best followed by idealized and present scenarios respectively (2.91/4.19/4.80 km).

In addition, the optimum school maps of years 2015 and 2020 did not look much different from each other (and from those of 2007). This results in similar efficiencies in the interested aspects (service area and travel distance) at all school levels.

มหาวิทยาลัยเทคโนโลยีสุรนารี

School of Remote Sensing Student's Signature Sirirat P.

Academic Year 2010 Advisor's Signature S. Dasanamda

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Sirirat Phongpippattanapan

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LIST OF ABBREVIATIONS

สพฐ	=	สำนักงานคณะกรรมการการศึกษาขั้นพื้นฐาน
BLN	=	Bang Len District
BMA	=	Bangkok Metropolitan Area
CLT	=	Clustering
CUAS	=	Central University Admissions System
ES	=	Existing School
ESA	=	Education Service Areas
GIS	=	Geographic Information System
GPMD	=	Gravity P-median Model
IIEP	=	International Institute for Educational Planning
L	=	Large-scale School (601-1500 students)
LA	=	Location-Allocation Model
LS	=	Lower-secondary School
M	=	Medium-scale School (121-600 students)
MOE	=	Ministry of Education
NCS	=	Nakhon Chai Si District
NES	=	Non-existing School Location
OER	=	Office of Education Reform
OHEC	=	Office of the Higher Education Commission
ONEC	=	Office of the National Education Commission
P	=	Primary-level School

LIST OF ABBREVIATIONS (Continued)

S	=	Small-scale School (1-120 students)
SCH	=	Number of Schools
SL	=	Service Loading
SM	=	School Mapping
SPR	=	Sam Phran District
TAM	=	Tambon
US	=	Upper-secondary School
VIL	=	Number of Villages
VL	=	Very-large-scale School (> 1500 students)

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CHAPTER I

INTRODUCTION

1.1 Research Background

Education is regarded as a fundamental key to the sustainable development of a country because it is a main root of major improvements in human lives, especially in the socio-economic and political aspects (Chimombo, 2005). In Thailand, the inefficiency of its existing educational system to initiate a prospective knowledge-based society has long been acknowledged by the government. As a consequence, the critical education reform program me was established in 1999 by the issuing of the National Education Act that aims to provide 12-years free basic education to all children and to reform the crucial education systems (under government control) at all levels to ensure their high operating efficiency and productivity (Office of the National Education Commission, 2010).

At present, the leading organization for the implementation of education reform required by the referred 1999 National Education Act is Office of the National Education Commission (ONEC) under cooperation of several core agencies, particularly the Office of Education Reform (OER) and Office of the Higher Education Commission (OHEC). One of the main objectives of the current education reform policies proposed by the Thai government is to reorganization of school administrative structures, especially at primary or secondary levels of education. This was initiated to provide more effective education services to the corresponding target groups all over the country.

This objective was partly implemented by issuing new Educational Service Areas (ESA) plan that can facilitate the high accessibility of children to the appropriate schools (at a given level) in their neighborhood. To achieve this task, specific service area for each state-run school was arranged by the responsible agencies based primarily on actual demand for school seats, school availability, and average travel distance to proper school of the target community. The two significant purposes of this school mapping scheme are (1) to provide equal opportunity in accessing appropriate school for all children and (2) to maximize cost/benefit of the state-run schools in organizing the high quality education service (สำนักงานการศึกษาขั้นพื้นฐาน, 2554).

Though the school mapping strategy is currently regarded as being a crucial part of state's education reform policy in Thailand but its systematic construction and implementation are still not much evidenced. One of the main reasons for this slow progress is the lack of proper tool to assist effective operation of the school mapping process. However, due to the rapid advance in geographic information system (GIS) technology, which is highly capable of storing, processing and presenting all kinds of spatial data, it now promisingly becomes a powerful tool for facilitating school mapping policy as required (for reviews see Hite, 2008).

Regarding to the stated reasons, this thesis is intended to demonstrate efficiency of GIS technology and location-allocation (LA) models (p-median and gravity p-median) in the preparation of suitable school location maps at district level in local Thailand under some preferred criteria. It is hoped that results obtained from the research can be used to improve efficiency of the formal education management system in the study area and can provide useful example of how to integrate the GIS technology and LA models to support school mapping strategy in Thailand in the near future.

1.2 Research Objectives

1.2.1 To establish GIS-based database on the appropriate criteria for location and allocation planning of schools.

1.2.2 To identify optimal school locations and allocations at present and in the future using spatial models.

1.2.3 To compare efficiencies of present school locations with locations derived from used spatial models.

1.3 Scope and Limitations

1.3.1 Study area is the Educational Service Area Office 2 within Nakhon Pathom Province covering 4 districts (as described in Figure 1.1 and Table 1.1).

1.3.2 Only the state-run primary and secondary schools are considered.

1.3.3 All potential students are assumed to attend public schools only.

1.3.4 Data contributed by the responsible agencies are valid.

1.4 Benefits of the Study

1.4.1 Effective GIS database of the relevant data needed in the study.

1.4.2 Knowledge on general efficiency of present school locations, principally in terms of the service area, service loading, and average travel distance to school.

1.4.3 Knowledge on optimum school locations (at each school level) identified by the idealized, p-median and gravity p-median methods at present and in the future.

1.4.4 Better understanding in the existing problems of present school management system and how to apply geoinformatics technology to solve some common problems.

1.5 Study Area

The preferred study area is Educational Service Area Office 2 in Nakhon Pathom Province including 4 districts (Bang Len, Nakhon Chai Si, Phuttamonthon, Sam Phran), 58 sub-districts (or tambons) and 443 villages with area cover of approximately 1,139.2 km^2 (Figure 1.1 and Table 1.1). There are 143 public schools in the academic year 2007 providing educations at 3 levels: primary (P) (or Prathom 1-6), lower-secondary (LS) (or Mattayom 1-3) and upper-secondary (US) (or Mattayom 4-6) (Figure 1.2 and Table 1.2). Among these, 104 schools have only P level, while 23 schools have both P and LS levels, and another 16 schools have both lower- and upper-secondary levels.

It was found that Bang Len District had highest number of the interested schools (53) while Phuttamonthon District had the lowest number (10) while Nakhon Chai Si and Sam Phran Districts have 40 schools each (Table 1.2). The lowest population density appears at Bang Len District (160.4 persons/km^2) and the highest one at Sam Phran District (740.33 persons/km^2). The largest district is Bang Len covering about 50% of the whole study area (in the upper half).

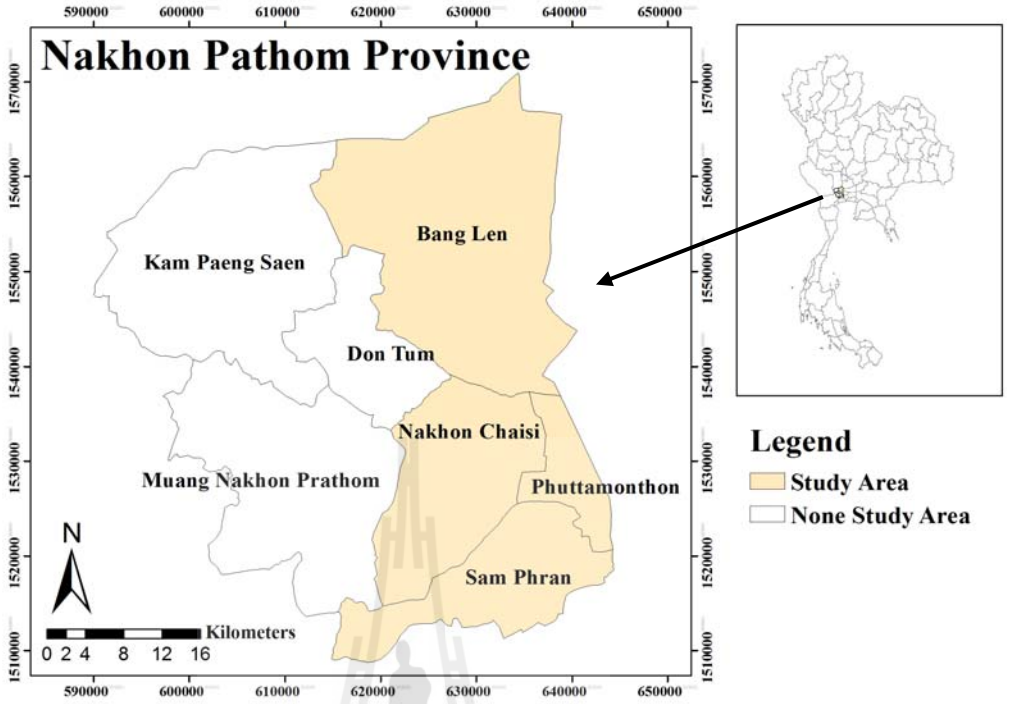


Figure 1.1 Map of the study area (Nakhon Pathom Education Service Area Office 2).

Table 1.1 General data of the study area (listed by district).

Official name		POP (2007)	Area (km^2)	POP density (per km^2)	Number of		Area/VIL (km^2)
English	Thai				TAM	VIL	
Bang Len (BLN)	บางเลน	87,760	574.93	160.40	15	180	3.19
Nakhon Chai Si (NCS)	นครชัยศรี	110,066	265.55	405.02	24	108	2.46
Phutthamonthon (PMT)	พุทธมณฑล	29,728	72.03	412.72	3	18	4.00
Sam Phran (SPR)	สามพราน	167,825	226.69	740.33	16	137	1.65
Total		394,420	1139.2	348.77	58	443	2.57

Note: POP = Population, TAM ≡ Tambon (sub-district); VIL ≡ Village;
Area/VIL ≡ Average area coverage per village.

Table 1.2 A numbers of schools included in the study (listed by district).

District	School level				School scale			
	P	**P/LS**	**LS/US**	**Total**	**S**	**M**	**L**	**VL**
Bang Len	41	8	4	53	23	29	1	-
Nakhon Chai Si	29	5	6	40	7	30	3	-
Phutthamonthon	5	3	2	10	2	5	-	3
Sam Phran	29	7	4	40	11	19	8	2
Total school	104	23	16	143	43	83	12	5
Percent	72.73	16.08	11.19	100	30.07	58.04	8.39	3.50

Note: 1. School level: P ≡ Primary, LS ≡ Lower secondary, US ≡ Upper secondary.

2. School scale: S ≡ Small (1-120 students), M ≡ Medium (121-600 students),
L ≡ Large (601-1500 students), VL ≡ Very large (> 1500 students).

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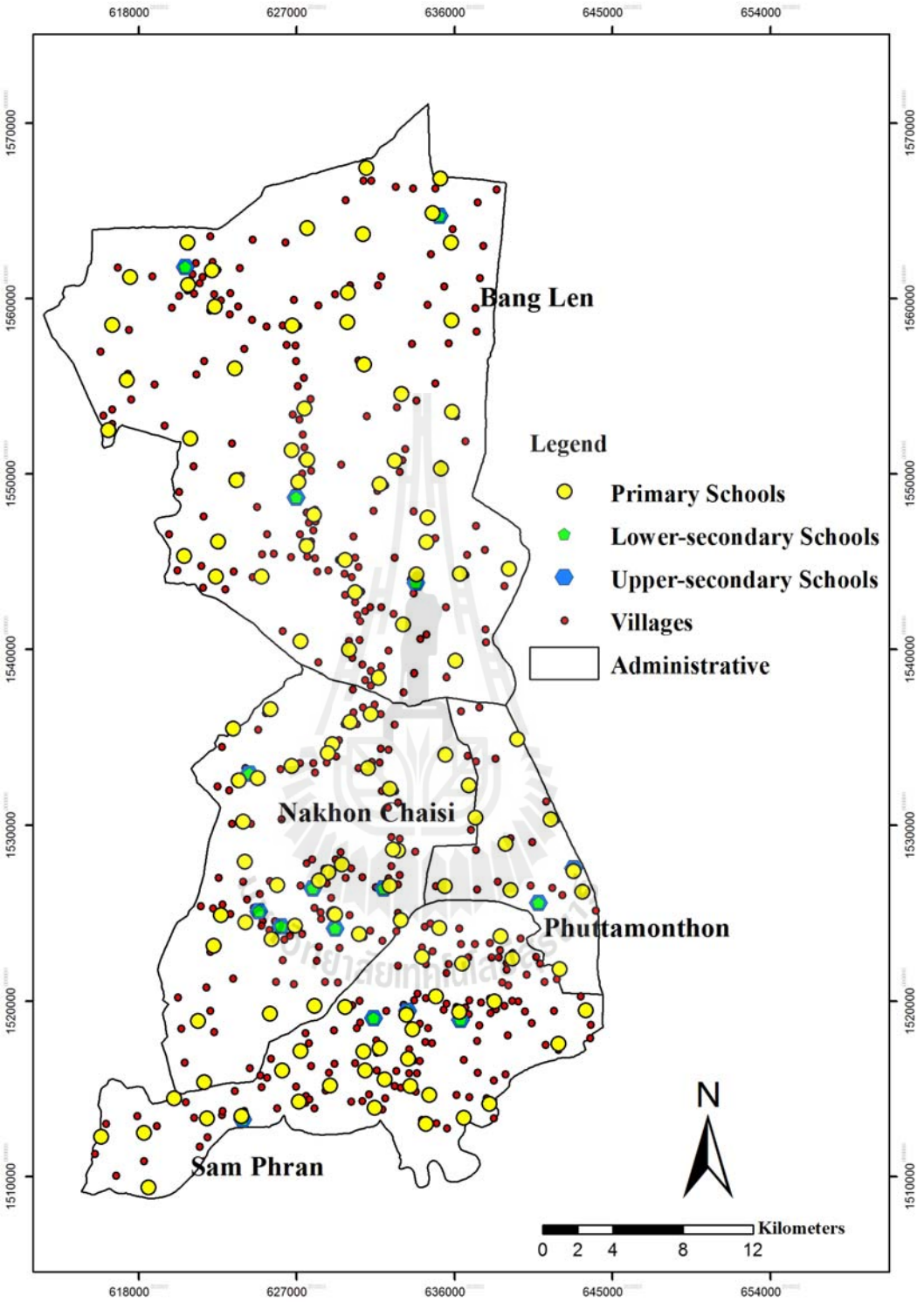


Figure 1.2 Location map of interested schools (143) and the surrounding villages (443).

CHAPTER II

LITERATURE REVIEW

2.1 Education System in Thailand

The official education services in Thailand at present are separated into four broad categories: (1) Early Year Education, (2) Basic Education, (3) Vocational and Technical Education, and (4) Higher Education (Figure 2.1). All of these stated services are under responsibility of the Ministry of Education (MOE) in association with several agencies at both local and national levels and their general details are as follows [contents are mostly from Ministry of Education (2008a) and (2008b)].

2.1.1 Early year education

The Early Year Education (or Pre-Elementary) program has been introduced to provide an early childhood education to children aged 3 to 5. While the majority of Early Year Education is organized by government's primary schools, the Ministry of Education has actively encouraged the private schools and local administrative bodies to take more significant role of this service. As a consequence, there has been a marked expansion in the provision of Early Year Education by the private sector. This is particularly evident in Bangkok Metropolitan Administration (BMA) where the private sector provides 59% of total Early Year Education, compared with the national average of 28%. The service is currently believed to cover more than 70% of the target children.

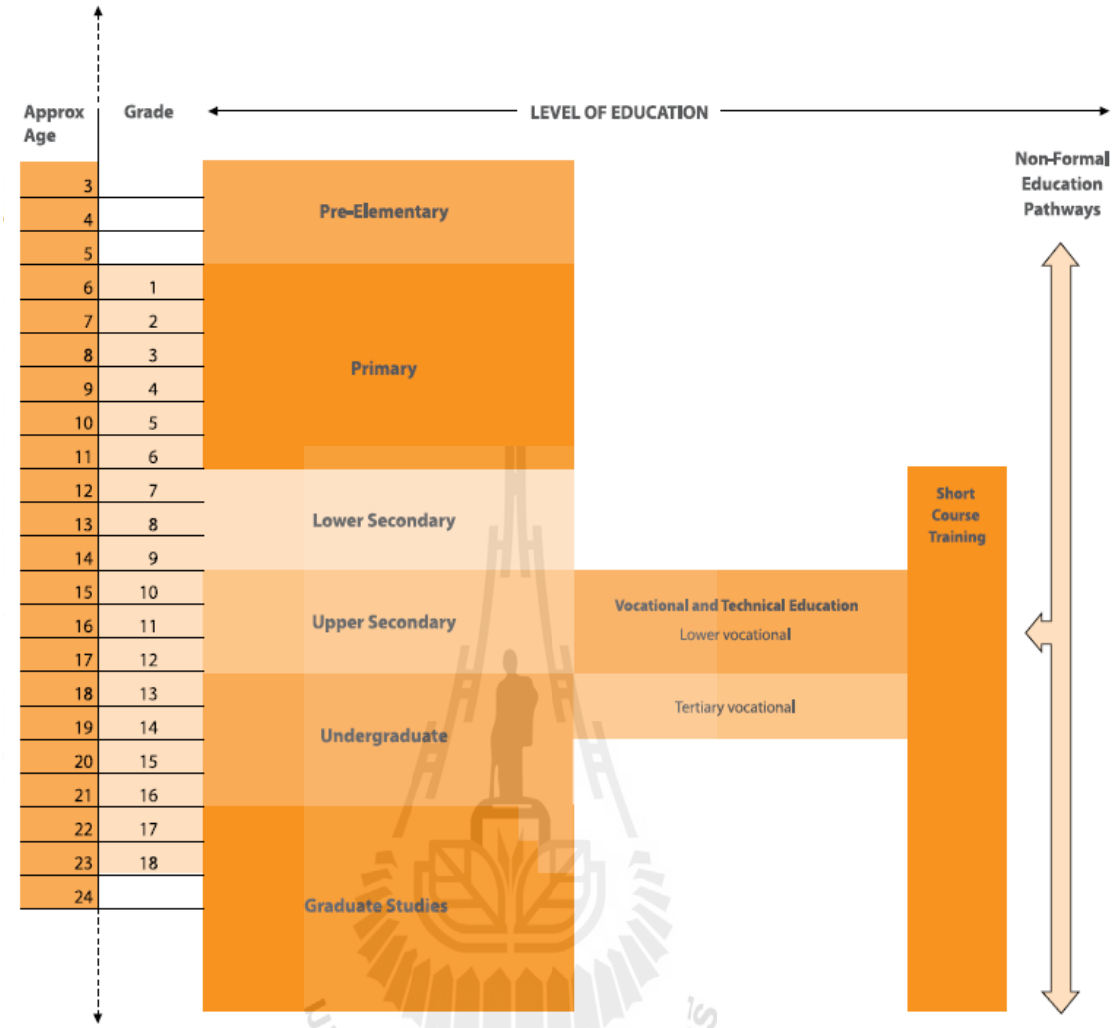


Figure 2.1 Structure of the formal Thai educational system.

From: Ministry of Education (2008a).

2.1.2 Basic education

The basic education in Thailand is separated into 3 levels: Primary (Prathom 1-6), Lower secondary (Mattayom 1-3), and Upper secondary (Mattayom 4-6). Enrolment for primary level begins at the age of 6. Primary education has been compulsory in Thailand since 1921 but the current six-years format just enforced in

1978. In 2003, the compulsory education was extended to 9 years with all children are expected to complete Mattayom 3 (at the minimum). This requirement has stemmed from the education reforming strategy described in the 1999 National Education Act which aims to provide 12-year free basic education to all Thai children and to reform crucial education systems (under government control) at all levels for obtaining high servicing efficiency and productivity. The gross enrolment rates of the school-aged children at all basic education levels in Thailand were relatively stable from 2003 to 2007. These are about 74-79% (primary level), 78.5-80.0% (lower-secondary level), and 34.3-35.0% (upper-secondary level).

2.1.3 Vocational and technical education

The formal vocational and technical education has been organized at three levels: (1) upper secondary (leading to the Lower Certificate of Vocational Education), (2) post secondary (leading to a Diploma or Vocational Associate Degree), and (3) university level (leading to a Degree). There are currently over 1 million students enrolled in the various vocational study pathways. Eight fields of the study are undertaken as majors: trade and industry, agriculture, home economics, fisheries, business and tourism, arts and crafts, textiles, and commerce.

2.1.4 Higher education

In the past, the means for student admission to the higher education sector is the High School Entrance Examination taken at the end of Mattayom 6 (Grade 12). However, the recent admission reforms have placed major priority on Grade Point Averages (GPA) and the CUAS (Central University Admissions System) examinations for final university entry of a student (CUAS, 2011). Higher education system is predominantly provided at universities and colleges under which two distinct

levels of educational attainment are the diploma level and graduate degrees. More than 2 million students are currently enrolled in the higher education sector and participation rates has increased significantly over the last few years from an average of 26% to the current average of more than 40%.

2.1.5 Administrative and organizational structures

As mentioned earlier**,** the 1999 National Education Act has introduced an overall reformation of the Thai Education System. This situation has led to considerable changes in the structure of educational management and administration system in order to support state's reforming policy written in the act. Primary emphasis is on the decentralization of administrative responsibilities to local level with the consolidation of education planning at the central level. The reforming process of the system led to the establishment of 175 Education Service Areas (ESA) in 2003 (this number has increased to 185 in year 2008) for taking care of the decentralization strategy and improving school managing efficiency at basic education level all over the country. Figure 2.2 illustrates a new managing structure for the organizations under control of the Ministry of Education (at central level) and for the ESA organization that are in use at present.

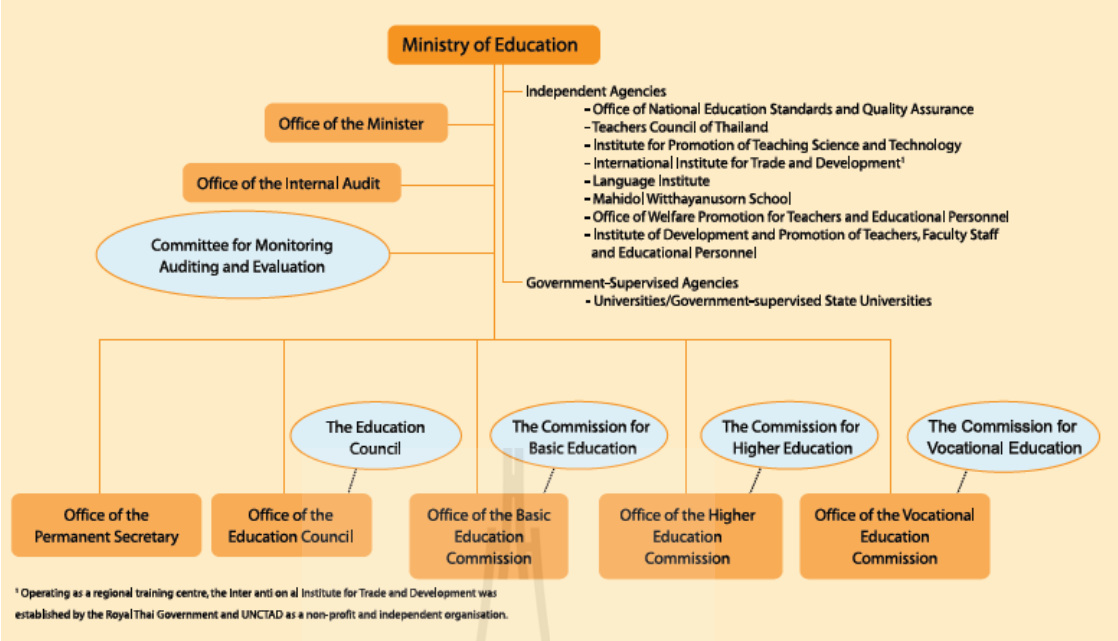


Figure 2.2a The administrative structure of education in Thailand.

From: Ministry of Education (2008a).

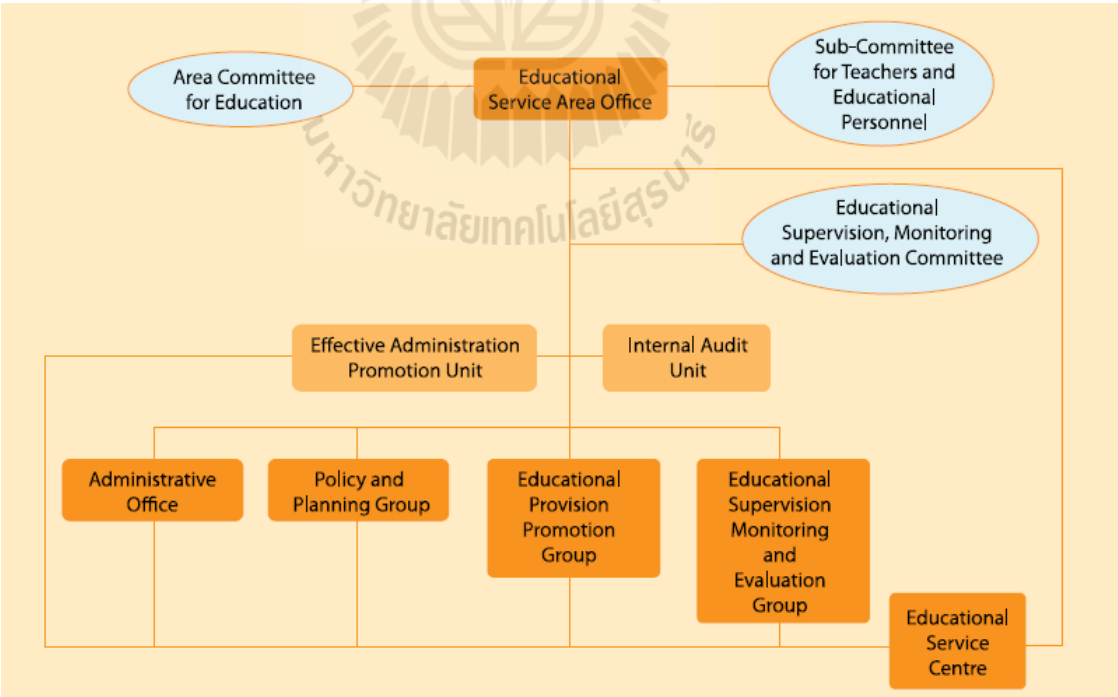


Figure 2.2b Organization of administration in Educational Service Areas.

From: Ministry of Education (2008a).

2.2 School Mapping Concept

2.2.1 The idea of school mapping

School mapping (SM) is normally applied to initiate effective planning of school locations and management strategies. It consists of set of techniques and procedures used to plan demand for school places at the local level and to decide on the location of future schools and the means to be allocated at the institutional level (Caillod, 1997). It has also been defined as a set of techniques and approaches that has a geographical perspective of education at its core (Mendelsohn, 1996). School mapping has been strongly advocated by the International Institute for Educational Planning (IIEP) over the past 50 years from its origin in France where efforts were then needed to place additional secondary schools on a rational, accessible and cost-effective basis (Caillods, 1983).

School mapping is a usual approach to the micro-planning of school locations and is also used to investigate and ensure the efficient and equitable distribution of resources within and between school systems when the large-scale reform or significant expansion of educational system takes place. The school mapping approach seeks to probe problems by documenting micro-level data variations and planning accordingly where its interest is on local-scale conditions, constraints, and solutions. There are three main steps needed in school mapping process of interest area as follows (see Figure 2.3 for example):

(1) An in-depth diagnosis of the existing educational situation in the base year.

(2) Estimation on present and future demand for school services (at village level).

(3) Preparation of the possible solutions based on the demand-supply assessment and knowledge on the school's service capability.

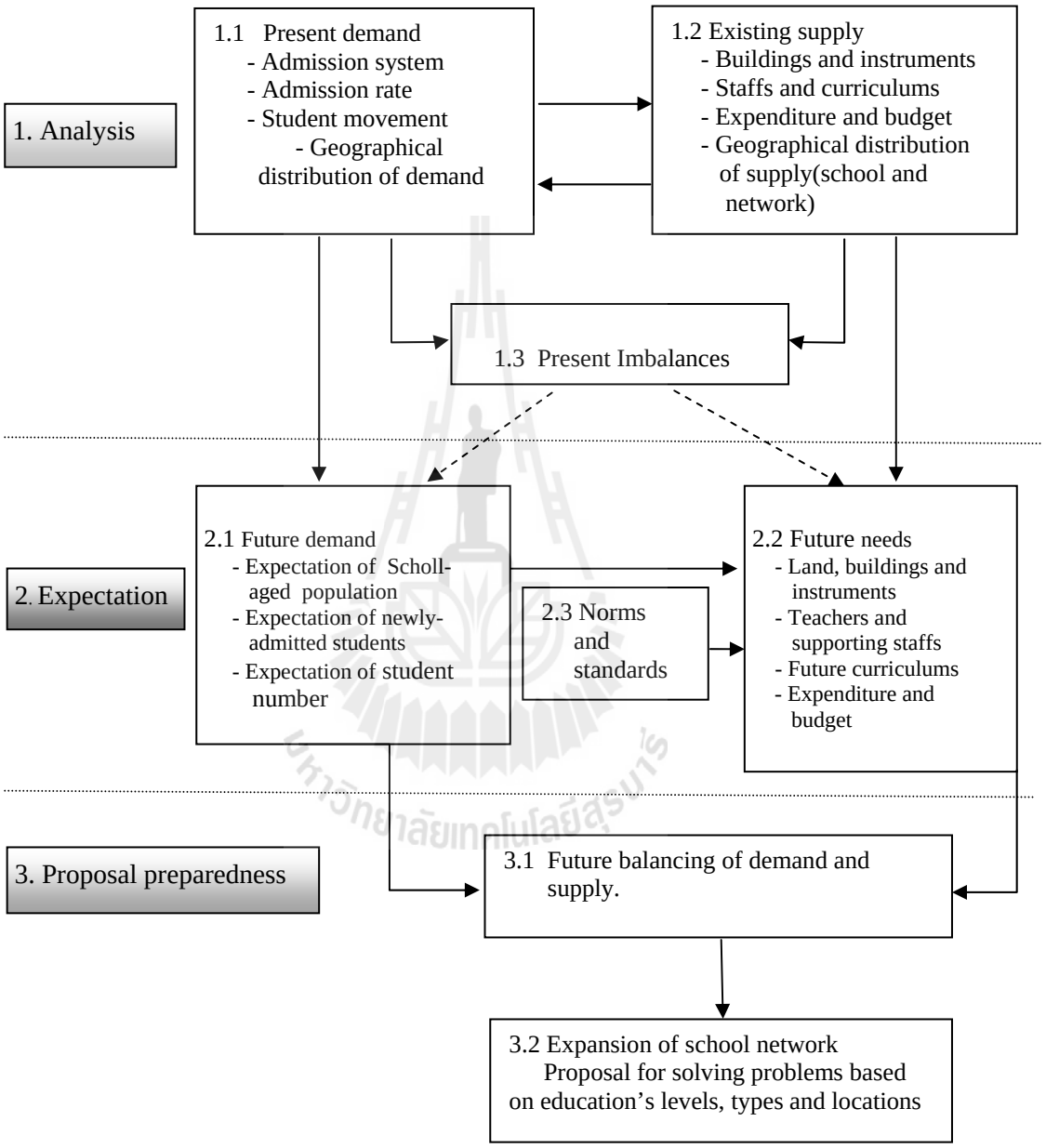


Figure 2.3 Conceptual diagram of the school mapping process.

Adapt from: สำนักงานการศึกษาขั้นพื้นฐาน (2554).

At the operating level, the definition of school mapping focuses on rationalizing physical location of schools based on demand perception between and within specified servicing areas and with a view to optimizing the use of human, material and financial resources. However, it implicitly refers to several other social and curricular aspects that call for attention of the educational planner (Govinda, 1999). In several countries where a school mapping methodology has been implemented, the goals of school mapping were typically concentrated on the following issues (Attfield, Tamiru, and Parolin, 2001):

(1) Providing basic education to all children of school age,

(2) Initiating an equality of educational opportunity by a geographical leveling off and equitable distribution of human, material and financial resources,

(3) Making the functioning educational systems more effective by improving the ratio between costs and performance, and

(4) Reforming structures, curricula, and methods of school's teaching strategy.

It should be noted that SM (a process) is not the same as a school map (typical product of the SM process like ones presented in Chapter IV). This is because, more than simply being a tabular, graphical or cartographical representation of a particular space or place, SM involves the consideration and inclusion of various forms of the technical data that impact and "populate" the physical and social context of the analysis. As a process that produces specific functional products, school mapping concept is fundamentally an educational micro-planning effort focused on increasing school resource efficiency and equity (Caillods, 1983; Varghese, 1997).

Education wastes can be tremendous if school mapping is unset. The Commission of Founding for Education Reforms (2001) suggests that prudence must be strongly taken about methods of organization and source allocations for education. This is because they are keys to determine its quantity and quality which can significantly impact the national social and economic structure. Therefore, resource selections from different sources must be geared to better effectiveness of educational organization in order to expand and avail education for all and with fairness. In 1999, Thailand has launched education reforms instituting new Educational Service Areas (ESA) that probably require survey to analyze that whether children in each ESA gain opportunity to totally be fundamentally educated, how many children have attended classes and so on. It counts that the desired educational organization requires lifetime learning process spearheading to promote quality citizens to gain knowledge and ability in living and to bring great benefit to societies which is the human resource development acquiring efficiency and meeting the needs of the nation.

The Commission of Founding for Education Reforms (2001) states that locating school need not adhere to sub-district zone or village but to the community density. Any zones with density of less than 100 households per 12.5 km^2 should not establish any new schools and schools should be situated at center of the community. The small size schools should be surveyed and mapped. They should be dissolved to the larger schools because the smaller ones are difficult to gain quality and students living near the school are not registered to study with the schools near their homes. According to Hallak (1977), in theory, the ideal school's service area should have a hexagonal shape to acquire the least overlapped service areas among schools locating relatively close to each other.

2.2.2 Applications of GIS to school mapping research

In recent years, a geographic information system (GIS) has become essential tool in planning school locations as discussed in Hite (2008). In essence, the GISs are computer-based programs that are highly capable in mapping, recording, displaying, and analyzing spatial data and interpreting relationships among associated data for making inferences. These capabilities make them become a promising tool in the processing of the preferred school maps (Maguire and Rhind, 1999).

GIS has been applied successfully to research in various fields, especially on the determination of suitable sites of directions to locate some essential facilities like road, hospital, or school. Among advantages for the GIS to assist education micro-planning, the following are identified by DeGrauwe (2002) and by Hite and Hite (2004):

(1) GIS helps make data presentation more attractive than traditional static maps.

(2) Projecting tabular data onto maps helps in recognizing "unexpected" situations which, now noticed, call for closer examination.

(3) Through considering geographical (spatial) factors, analysis becomes "finer" and more precise, increasing the likelihood that ensuing strategies will be more pertinent.

(4) More flexible assistance can be provided in prospective planning at multiple levels or units of analysis: national, regional, provincial/district, and local.

(5) Expanded "holistic" representation and exploration in contexts of schooling through the direct and dynamic use of multiple sources of influential data such as those found in census, transportation, utilities, health care, land use, and

agricultural databases which are otherwise very difficult to include in education planning and management.

(6) Increased public appeal and utility.

(7) Extensive control in the scale of complexity: extensive flexibility in how much data are displayed/explored at a given time, with changes in unit of the analysis virtually immediate.

(8) Dynamic ability to facilitate “what if” condition analysis, exploratory inquiry, and creation of planning and management “scenarios”.

In recent years, GIS has become essential tool in school mapping analysis as seen in several reports. For examples, Moller and Jensen (2008) used GIS on the LA model to evaluate relationship between school locations and number of students in Copenhagen, Denmark. They found that the school locations fit their surroundings and students with residences nearest to any schools need to be admitted to the schools. Transport networks are another key to travel to schools. In addition, walking, bicycling, taking bus and taking private cars to school affect travels and the expenses. Had schools not been considerably distant from the residences, it would save both time and money. Further, it is useful for educational planners to decide which schools should admit more students or which ones should reduce their admission. This betters the school quality.

Gilo (1997) has investigated master planning fit location for schools in Tel Aviv, Israel using geographic information. He found that the GIS is the best instrument and best efficiency to master planning fit locations for schools. Conditions for consideration are distance of walking for students from home to schools, school sizes (admission ability), transportation networks and public spaces. By adopting these

factors, it was found that many schools need changes of location due to, e.g., few roads to access or being adjacent to highway and unable to cross it to school. Such reasons can affect school locations which should be changed for properness. It was further evidenced that some service areas of some schools are too wide turning students spend surplus time to reach their schools. The conclusions were that (1) two new schools should be established to admit not more than 540 students and the most distance is 1,500 meters and (2) three new schools should be established in fit location after applying location allocation method.

Zhang, Zhou, Zhang, and Hou (2008) used GIS to determine proper service areas for public schools in Chaoyang District, southern Changchun, China, based on two main aspects: school's ability to enroll students and how many students that the district can produce. The main objective of the work was to find optimum solution that induces minimum travel distance to school of all students under specified capacity of the relevant schools. It was found that GIS can be used efficiently in finding that solution in the study area.

The school mapping process was also performed in Tanzania by Galabawa, Obeleagu, and Miyazawa (2002). Its general purposes were as follows: (i) to strengthen local capacities to collect, organize, analyze and apply educational data to make informed decision for educational development; (ii) to improve districts' administrative, planning and monitoring capacities with respect to education; (iii) to mobilize local community members to participate in the development or improvement of education; and (iv) to put in place accurate/reliable, detailed and accessible education information for use in decision making and action. The school mapping scheme was adapted and used the instruments and techniques developed by the

International Institute of Educational Planning (IIEP). It was found that to gain maximize profit, school mapping process should be a long-term strategy not just a short-term one.

Peng, Li, and Zhan (2007) employed LA modeling for primary school accessibility and catchments analysis at Wuhan, China. The two main objectives proposed in this work are (1) to examine availability and efficiency levels of school and assess the demand-supply balance between students and schools capacity and (2) to identify new potential location and evaluate the feasibility of LA model for planning additional schools in Wuhan. Four experiments with different hypotheses were implemented to test the above objectives. The results showed that the service area of each school can be delineated according to the school capacity and the accessibility of schools is highly correlated with school capacity. This result provides urban planners tools to make decisions concerning where to increase or decrease school capacity, to combine schools or plan new schools.

Similarly, Pizzolato, Barcelos, and Lorena (2004) applied operation research to establish public schools in Rio de Janeiro, Brazil, where students simply walk to schools from home. The least total sum of distance between residences and schools is preferred to find optimum locations. The obtained results suggested best school locations and recommend on short-term and long-term administration.

In Thailand, Rattana Rujirakul applied GIS to evaluate locations and elementary education service areas in Muang District, Nakhon Ratchasima by studying models from research papers and developed models using population and transportation variables by allocation analysis. Results found in the study were used to evaluate proper locations and elementary education service areas in Mueang District, Nakhon

Ratchasima and to create the map locating proper locations and elementary education service areas, which can be applied to improve the improper ones. (รัตนา รุจิรกุล, 2548)

2.3 P-Median and Gravity P-Median Models

Location-allocation (LA) model is a mathematical algorithm normally applied in the resource management analysis in order to balance demand and supply and maximize the efficiency. In the GIS context, the word allocation indicates the process of identifying specific areas, districts, road segments etc. surrounding a centre; areas that should “serve” the particular centre concerning the in- or outflow of people or goods, generally known as “demand”. There might be more or less demand than the centre can “handle”- specified by “supply” or “capacity” of the centre. The word location, on the other hand, indicates the process of identifying optimum locations for new centers given a set of objectives related to, for example, accessibility. A being a part of the GIS network analysis tool package, allocation modeling assumes that the area surrounding a centre is represented as a network of linear features. These linear features identify location of possible transport routes and indicate how these routes are connected to each other, and reflect the fact that transportation of resources on the ground normally takes place along certain pre-defined corridors. Each linear feature in the network has associated impedance value indicating cost (measured in meters, minutes, petrol etc) of moving along this line. This impedance value will often be related to specific means of transportation.

2.3.1 Concept of the p-median model

The p-median problem is probably the most applied location-allocation

model. In essence, it is a LA model that takes into account the total distance between demand points and service points (facilities). This algorithm is normally used to determine best locations to place limited number of the service points (e.g., supermarket, hospital, police station, fire station, dump site or school). For reviews see Mirchandani and Francis (1990) and Current, Daskin, and Schilling (2002). Demand is generated at a set of demand points (nodes in a network environment) and given as a weight. Proper locations for p facilities are to be found by the model's simulation. Each customer is serviced by the facility located closest to them only. The objective function is to minimize the total travel time of all customers. Concept of the p-median model can be summarized as follows (Marianov and Serra, 2009):

"Given the location of *n* points that house known amounts of demand, designate *p* of these points as facilities and allocate each demand to a facility, in such a way as to minimize the total weighted distance between demands and facilities"

The crucial input data for the model are as follows (Ruslim and Ghani 2006):

1) Finite number of demand points (with demand values) to specify the location and amount of demand that needs to be satisfied.

2) Finite number of potential facility locations (or service points). These are the preferred positions where facilities can be established.

3) Distances between demand points and the facility locations. Depending on the problem, these can be calculated from network analysis or Euclidian distances.

4) Specific positive integer number (p) of required facilities needed to be known.

In principle, an optimization algorithm tries to find a solution for the objective function that returns a minimal (or maximal) value. For the p-median study, the objective function is total distance from every demand point to the closest service point within the configuration. The travel distance is weighted (or multiplied) by a population number of the demand point. A crucial constraint is that each demand must be assigned to its closest facility only (the total number of available facilities is p) (Reese, 2006).

Algorithm of p-median problem can be illustrated mathematically using following notations (Varsic and Predic, 2011):

I = {1,…, M} is set of demand points

J = {1,…, N} is set of potential facility locations (service points)

P = {1,…, p} is set of demand points

x_{ij} = 1 (if customer at demand point i allocated to service point j), otherwise $x_{ij} = 0$

y_j = 1 if a facility is established at location j, otherwise yj = 0

D_{ij} = Shortest distance between location i and location j

w_i = Number of population at demand point i.

Then, the p-median problem can be formulated in the following manner:

$$\text{Minimize} = \sum_{i \in I} \sum_{j \in J} w_i D_{ij} x_{ij} \qquad (2.1)$$

Subject to

$$(1) \sum_{j \in J} x_{ij} = 1 \text{ for } \forall i \in I \qquad (2) \sum_{j \in J} y_j = p \text{ for } \forall i \in I$$

$$(3)\ x_{ij} \le y_j \text{ for } \forall i \in I, \forall j \in J \qquad (4)\ x_{ij} \in \{0,1\},\ y_j \in \{0,1\}$$

This model can be used when each node is a point of demand as well as facility site or when a set of eligible sites is restricted to some predefined discrete set of network points. The objective function (2.1) is proposed to minimize total weighted distance of the assignment. When the demand node i is assigned to a facility located at j ($x_{ij} = 1$) then the associated term w_iD_{ij} is included in sum. The first constraint (1) is to ensure that each demand point must be assigned to at least one facility point while constraint (2) restricts the placement or allocation of the facilities to exactly p facilities of interest. Constraint (3) maintains that any such assignment must be applied to only those sites that have been selected for a facility. The final constraint (4) restricts variables to 0 or 1 values.

2.3.2 Concept of the gravity p-median model

General concept of the gravity p-median model was proposed by Drezner and Drezner (2007) based on the integration of gravity rule in economic location-allocation planning and the standard p-median model mentioned earlier. Reilly (1931) proposed the gravity rule to conceptually explain how people tend to patronize different supermarket of their interest. According to this theory, suppose a customer resides in an intermediate town near the two large cities, the probability that he/she will patronize one of the cities is proportional to city's size and inversely proportional to the squared distance from that city. This rule was later applied in critical works of Huff (1964, 1966) to model consumer behavior in selecting a store to patronize. He asserted that the probability that a customer patronizes a store (or shopping mall) is proportional to the store's floor area and inversely proportional to some power of the distance to the store. He applied gravity model to consumer choice behavior and generalized the distance decay function from the square of distance to

some power of distance depending on the retail category. The gravity model was extended by Nakanishi and Cooper (1974) who suggested replacing floor area with multiplicative competitive interaction (MCI) as the measure of store's attractiveness.

Over the years the gravity rule was applied to several retail categories and various distance decay functions were proposed for its implementation, see Drezner (1995) for a review. For examples, Jain and Mahajan (1979) and Bell, Ho, and Tang (1998) applied it to the grocery stores. Wilson (1976) and Hodgson (1981) had applied an exponential distance decay function to their work. Ripley (1993) applied it to explain the motion event such as the influence of retailing in the city. It is similar to Hartshorne (1990) who modified the gravity model for the use in investigating retailing. He found that the service point of the retailing shop in general is small and people will never walk far to buy goods. Customers attracted by high quality goods will walk farther. In addition, Wimonporn Paisopa (2003) used gravity model to model travels of city dwellers, outskirt dwellers and rural dwellers in the city plan of Chiangmai. She found that main variables affecting the used model are number of students, parents' income, accessibility which influence in selecting service points. Wallapha Pornpatcharaphong (2005) applied the gravity model to analyze scope of the service point of the secondary schools in Nakhon Ratchasima Province and found that the school fame affects decision in selecting a school.

The gravity p-median model was developed as being more realistic form of the popular p-median model because a crucial assumption in the standard p-median problem is that customers select the facility closest to them. This may become valid assumption if customers are directed by a central command to the closest facility (e.g. being forced by law), or when customers have complete information about

distances and select facility in a rational manner. It is also implicitly assumed that all the available facilities are equally attractive. In reality, this is seldom true for most customers as they usually tend to make selection of facility to patronize based on several factors apart from the distance factor.

The gravity p-median problem assumes a more realistic scenario that customers divide their patronage among the available facilities with the probability that a customer patronizes a facility being proportional to the attractiveness scale of that facility and to a decreasing utility function of the distance to that facility. This distance-based factor is normally called “distance decay function” that could be described in several forms, e.g. inverse square form, power form, or exponential form. Similar to p-median model shown in Eq. 2.1, the gravity p-median model can be written in general form as

$$\text{Minimize} = \sum_{i \in M} \sum_{k \in P} w_i R_{ik} D_{ik} \; ; \quad R_{ik} = \frac{U_{ik}}{\sum_{j \in P} U_{ij}} \tag{2.2}$$

where R_{ik} is the probability function that indicates the proportion of total customers w_i residing at demand point i that is given to the facility k and U_{ik} is the attractive function, which depends on the facility’s own attractiveness level and the chosen distance decay function. For example, $U_{ik} = C_k/D_{ik}^2$ (for the inverse-square form) or $U_{ik} = C_k/\exp(aD_{ik})$ (for the exponential form), where C_k is the attractiveness level of the facility k.

2.3.3 Applications of p-median and gravity p-median models

The p-median and gravity p-median models have been applied fruitfully in several researches conducted in the past on the location and allocation purposes. Examples of the reported works are as follows.

Harvey, Hung, and Brown (1974) employed the p-median model to fix number and the center location of a hospital in Sierra Leone by studying a one-fold level of the problem. They were also aware on interactions between the low-high levels of hospitals. Reilly (1976) employed p-median model to analyze problem of the hospital location and its emergency ambulance for best service management by conditioning on the shortest distance and least time to travel from the incident spot to hospital. Calvo and Marks (1973) used p-median model with the medical service planning. The hierarchical model showed that the model able to best access the service stations, minimize cost but maximize benefits.

Banerji and Fisher (1991) employed both the p-median model and the hierarchical model to plan proper location for service station in India. They set the hierarchical model as a network, i.e. high level affairs providing the lower level of services, and found that the demand points are enabled to best use of the service points with the shortest distance.

Drezner (2006) used the gravity model in studying multiple facilities location in the plane using the Gravity median two problems are considered in this article. The first problem is the p median where the total distance traveled by customers is minimized. The second problem focuses on equalizing demand across facilities by minimizing variance of total demand attracted to each facility.

Drezner and Drezner (2007) used the gravity p-median model to calculate gravity towards customers divide their patronage among the facilities with the probability that a customer patronizes a facility being proportional to the attractiveness of that facility and to a decreasing utility function of the distance to the facility.

CHAPTER III

REASEARCH METHODOLOGY

3.1 Conceptual Framework

This research consists of 3 main parts in according with the objectives described in Chapter I (see flowchart in Figure 3.1). The first section devotes to the development of GIS database necessary for further study. These data were acquired from 3 main sources: (1) responsible agencies, (2) internet resources, and (3) field surveys, and can be separated into 3 main categories (as described in Table 3.1):

(1) General data of the area; e.g. road network map or administrative map.

(2) School data; e.g. location, official name, or number of students, and teachers.

(3) Tambon/village data; e.g. location, area cover, or number of population.

In the second part, efficiencies of the existing schools (primary, lower-secondary, and upper-secondary levels) are assessed in terms of the service area, service loading, and travel distance to school. These results are then compared with those obtained from other two methods: idealized and the p-median model. The optimal location maps of schools for present scenario (year 2007) and future scenarios (years 2015 and 2020) at each school level are also created using the p-median model and their efficiencies are subsequently evaluated based on methods formerly applied to the existing schools stated earlier.

In the third part, optimal location maps for the upper-secondary schools at present (year 2007) and in the future (years 2015 and 2020) are generated using the gravity p-median model and their efficiency in term of travel distance is subsequently evaluated. The obtained results are then compared with those from the idealized method and the p-median model.

Major results of the work mentioned in the first part are reported and discussed in this chapter whereas results of the works stated in the second and third part are presented and discussed in Chapters IV and V, respectively.

Table 3.1 Details of the essential data included in the database construction.

Data class	**General data**		
	Specific details	**Format**	**Source (year)**
Administrative map	District/tambon boundary	Polygon	Department of Provincial Administration (DPA) (2009)
Road network	Available road network	Line	City Planning Department (CPD) (2009)
Data class	**School data**		
	Specific details	**Format**	**Source**
Location	Geographic location	Point/map	Internet, **surveys (2007)**
Name/details	Official name and general details	Attribute	Nakhon Pathom Education Service Area Office 2 (2007)
Teachers/students	Numbers at class/educational level		
Class rooms	Numbers at educational level		
School area	in "rai" and m^2		
Admission rate	Annual data at educational level		
Accessory data	E.g., Administrative board.		
Data class	**Tambon/Village data**		
	Specific details	**Format**	**Source**
Location	Geographic location	Point/map	The Bureau of Registration Administration (2009)
Name/details	Official name and general details	Attribute	
Population	Number at tambon/aged level		

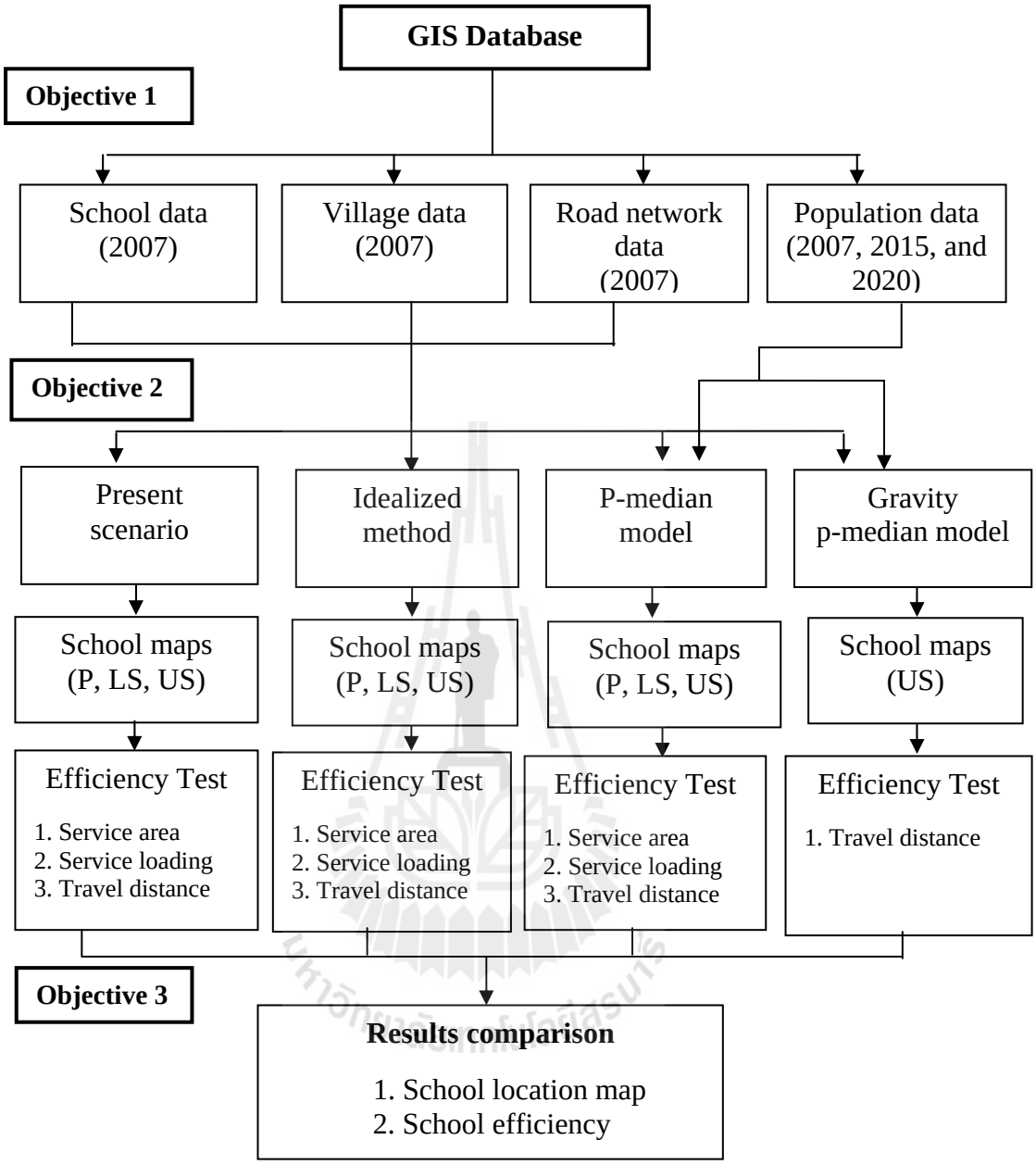


Figure 3.1 Conceptual framework of the entire research procedure.

3.2 Research Methodology

The entire research procedure has been divided into 5 major sections in according with the conceptual framework (Figure 3.1) as follows.

3.2.1 Construction of the GIS database

(1) Assemble interested data from corresponding sources (as listed in Table 3.1), then categorize and keep them in form of the GIS database. The school/village map with road network as a background is shown in Figure 3.1. Detailed procedure of the database construction is illustrated in Section 3.4.

(2) Estimate population data (at tambon/village level) in years 2015 and 2020 based on relevant records during years 1998-2007 (assuming uniform linear changes during years 1998-2020). The computing process is detailed in Section 3.5.

3.2.2 School efficiency assessment for present situation

(1) Generate location map of the interested 143 schoolsand their surrounding 443 villages in the study area (result is illustrated in Figure 3.2).

(2) Evaluate efficiencies of existing schools (at each level) in terms of the service area, service loadings, and average travel distance to school of students, under the given criteria of travel distance and choice of preferred school for students. An assumed service area of each school was defined by proposed distance limits along existing road network. These are 1-5 km (P level), 3-7 km (LS level) and 5-10 km (US level). Typically, service area will rapidly grow with higher distance limit which results in great reduction of the no-service area and also the substantial increase of overlapped service area.

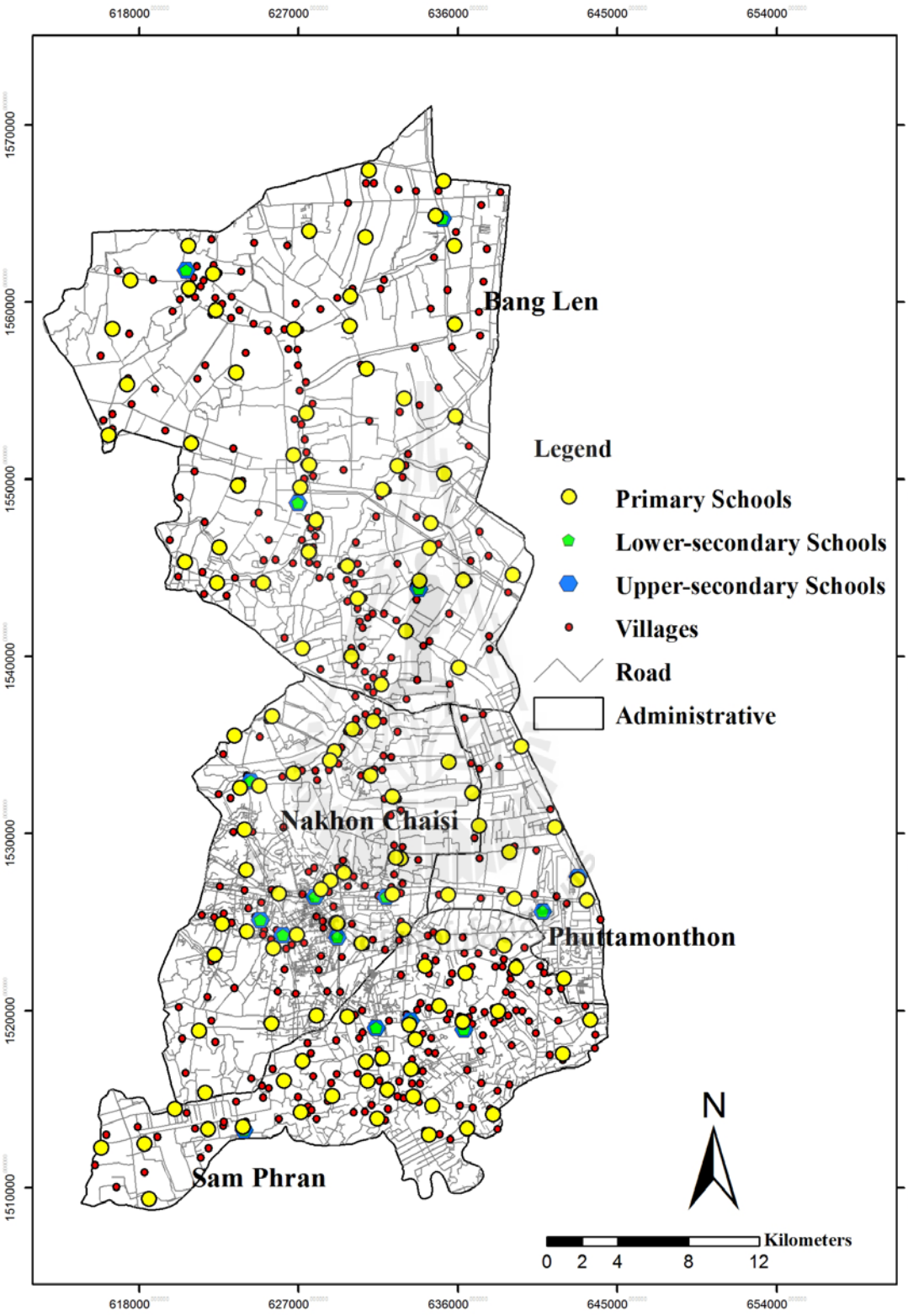


Figure 3.2 School/village location map with road network as a background.

The service loading value of a considered school is defined by

$$\text{Service loading (SL) (in \%)} = \frac{\text{ACT}}{\text{POT}} \times 100 \qquad (3.1)$$

where ACT is number of actual students (at the interested level) found at that school and POT is the potential students (at the interested level) residing in the given distance limit. The potential students (at each village) are determined by age level of its population data: 6-11 (P level), 12-14 (LS level), and 15-17 (US level). Five classes of the SL values are proposed in this thesis (Table 3.2): low (L), medium low (ML), medium high (MH), high (H), and very high (VH).

In term of service loading (SL), the preferred schools should not have too low or too high of the SL values. The recommended range of proper SL for the P and LS schools is 50-150% in according with the current state's policy that requires all children to attend 9-year compulsory education (a 100% enrolment). School with a relatively low SL values (e.g. SL<50) indicates its inefficiency to attract potential students living within its service area to attend the school and the major causes of such failure should be examined. In the contrary, a school with relatively high SL values (e.g. SL>150) mean it can attract large amount of potential students that live outside its normal service area to attend the school and knowledge of main factors contributing to its success are valuable for the further improving of some less success schools (ones with much lower SL). In general, a school with SL values of 50-150% indicates its moderate capability to attract potential students residing within its service area to attend the school (for the education at P and LS levels) when compared to the average rate of school enrolments at P and LS levels nationwide that stands at about 80% (MOE, 2008a).

Table 3.2 Classification of the service loading values.

SL level		SL Range		SL meaning
		P and LS levels	US level	
Low	L	0-50%	0-15%	Critical
Medium low	ML	50-100%	15-30%	Normal
Medium high	MH	100-150%	30-50%	Normal
High	H	150-200%	50-100%	Concerned
Very high	VH	>200%	>100%	Critical

Note: Critical (L) = School is considered in a critical state as it fails to attract enough students to attend (when compared to number of expected potential students residing within.

Critical (VH) = School is considered in a critical state as it over-succeeds in attracting students to attend (when compared to number of expected potential students residing within its service area). This might be destructive for the operation of the less-attractive nearby schools (at the same level).

Normal = School is considered in a relatively comfort state as it can attract a satisfied amount of students to attend (when compared to number of expected potential students within its service area).

Concerned = School is considered in a concerned state as it begins to over-succeed in attracting students to attend (when compared to number of expected potential students residing within its service area). This might be destructive for the operation of the less-attractive nearby schools (at the same level).

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At present, the average rate of attending schools at primary and lower secondary levels in Thailand is approximately 80%, which is in contrast to the attending rate at the US level that stands at about 35% (MOE, 2008a). Therefore, in term of service loading, the public US schools with SL values of 30-50% should be regarded as being moderately successful ones in recruiting potential students to attend their places (different from what is expected from P and LS schools). As a result, efficiency of schools in term of SL value is examined separately for class of the P and LS schools and the US schools as illustrated in Table 3.2. Typically, the mostly-

concerned ones are small schools with low SL values as they are less effective in attracting students to come for their services.

The average travel distance was calculated by assuming that a student can attend only one school locating closest to their residences (at the corresponding village location) and there is no limit on student's travel distance (similar to that of the p-median model). There are two distance-based parameters being considered here: maximum travel distance and average travel distance (per student).

3.2.3 School efficiency assessment based on idealized method

(1) Identify the preferred numbers of functioning school at each educational level. This was achieved by assuming that the ideal service area (for a school) has a hexagonal shape. Then the preferred number of schools (at each level) can be determined, which are 50 for P and LS levels and 18 for US level (Table 3.3). These numbers were gain based on the method described in Section 3.3.

(2) Construct associated school location maps based on ideal numbers of schools obtained in step (1) and the suitable school locations systematically selected based on the following prescribed priorities:

(2.1) Be location of the existing medium/large schools with moderate or high SL values. The existing small schools (especially at primary level) are largely ignored except ones that are substantially needed in the remote area.

(2.2) Locate within villages/tambons that have relatively high population density.

(2.3) Have relatively high amount of potential students residing within specified service area (3 km-distance for P and LS level and 5 km-distance for US level).

(2.4) Provide well-distributed school map in which the chosen sites do not situate too close to each other (e.g. >3-5 km apart).

These stated criteria were assessed throughout the study area (for all schools and tambons) and suitable locations (at each school level) were identified and mapped. Their corresponding service areas are also shown on the obtained maps.

Table 3.3 Numbers of preferred schools by the idealized method.

District	P Level		LS Level		US level	
	Original	**Idealized**	**Original**	**Idealized**	**Original**	**Idealized**
Bang Len	49	23	12	20	4	5
Nakhon Chai Si	34	12	11	12	6	6
Phutthamonthon	8	4	5	6	2	2
Sam Phran	36	11	11	12	4	5
Total	127	50	39	50	16	18

Note: 1. At P level, all 50 chosen sites are the existing medium/large P or P/LS schools. Only two small schools (SB6 and SB7) were chosen to serve some remote areas (Table C1.1).
2. At LS level, out of 50 sites chosen, 39 are the existing P/LS and LS/US schools and 11 are the additional medium/large scales P schools seen fit to the preferred map (Table C1.2).
3. At US level, out of 18 sites chosen, 15 are the existing LS/US schools and 3 are the additional P/LS schools seen fit to the preferred map (Table C1.3).

Most selected locations (for all levels) are the existing medium/large schools with moderate/high SL values that are well distributed throughout the area. Some school sites in the remote region were selected just to reduce gaps of the current service area map (to reduce no-service areas). These new maps are created to reduce amount of overlapping service areas and no-service areas, and to eradicate some ineffective small schools.

(3) Consider efficiency of the identified school locations from (2) (at each level) in terms of service area, service loading, and average travel distance to school, under the given criteria of travel distance limits [1-5 km (P level); 3, 5, and 7 km (LS level); 5, 7, and 10 km (US level)], and choices of preferred school for students. The entire process is similar to ones described earlier in Section 3.2.2 (for the present situation) but the calculation of SL was more complicated as it greatly depends on how we transfer existing students from the not-chosen schools (at present) to preferred schools given by the idealized method also. The assumption adopted here is that all students of the neglected schools (at each level) are transferred to any chosen school (at that level) that locates closest to them only.

(4) Compare and discuss results obtained from 3.2.3(3) (idealized) and 3.2.2(2) (present scenario). Some suggestions for better school management are also given.

3.2.4 School efficiency assessment based on p-median model

(1) Select potential sites of being school locations (at each level) and define ideal number of schools required in the creation of the school maps (at district level). Potential sites are identified in according with criteria described in Section 3.2.3(2) where priority is given to the appropriate existing schools that are not situate too close to each other and to villages or tambons with high population residing within the given distance limits (see more details in Appendix D). Numbers of the potential and preferred school sites (at each school level) for each district are as described in Table 3.6.

(2) Produce optimum school location map (for each district) that gives minimum value of total travel distance to school using p-median model. Concept of

the used model is described in Chapter II and results are reported in Chapter V.

Table 3.4 Numbers of potential/ideal school sites (p-median).

District	P level			LS level			US level		
	POS	**PRS**	**PC**	**POS**	**PRS**	**PC**	**POS**	**PRS**	**PC**
BLN	30 [30,0]	25 [25,0]	142,506	30 [12,18]	25 [14,11]	142,506	15 [4,11]	9 [3,6]	5,005
NCS	24 [24,0]	12 [12,0]	2,704,156	24 [11,13]	12 [8,4]	2,704,156	24 [5,19]	4 [3,1]	10,626
PMT	5 [5,0]	3 [3,0]	10	5 [5,0]	3 [3,0]	10	3 [3,0]	1 [1,0]	3
SPR	16 [16,0]	10 [10.,0]	8,008	16 [11,5]	10 [5,5]	8,008	16 [4,12]	4 [2,2]	1,820
Total	75 [7,0]	50 [50,0]	-	75 [39,36]	50 [30,20]	-	58 [16,42]	18 [9,9]	-

Note: 1. POS = Potential sites, PRS ≡ ideal sites, PC ≡ Possible combinations for potential solutions.

2. [ES,NES] = [Existing school, Non-existing school].

3. At P level, all potential sites are the proper existing P or P/LS schools, while at LS and LS level, some proper not-existing school locations (tambon sites) are also included.

(3) Examine efficiency of the chosen school locations from (2) (at each level) in terms of the service area, service loading and average travel distance under the prescribed criteria [like ones applied to the assessment of idealized school maps in Section 3.2.3(3)].

(4) Compare and discuss results gained from 3.2.2(4) (present scenario), 3.2.3(3) (idealized scenario), and 3.2.4(3) (p-median scenario). Some suggestions were also given about the reorganizing of existing school locations.

(5) Perform steps (1)-(3) but using population data of years 2015 and 2020, and compare results with those of the year 2007 situation (p-median scenario). The used potential sites for these two years were assumed to be the same as those in year 2007.

3.2.5 School efficiency assessment based on gravity p-median model

(1) Select potential sites for being US school locations and define number of the school needs in the formulation of school maps (at district level). All potential sites are systematically identified based on the aforementioned criteria given in Section 3.2.3(2). There were 59 potential sites proposed for 18 sites preferred as described in Table 3.5 and in Appendix D (for comprehensive details).

Table 3.5 Numbers of potential/ideal sites (gravity p-median).

District	Potential locations			Preferred locations			Possible combinations
	Total	ES	NES	Total	ES	NES	
BLN	15	4	11	9	4	5	5,005
NCS	24	6	18	4	1	3	10,626
PMT	4	2	2	1	0	1	4
SPR	16	4	12	4	2	2	1,820
Total	59	16	43	18	7	11	-

Note: ES = Existing school, NES ≡ Non-existing school.

(2) Determine attractiveness values for each potential site based on number of the population living within 5km distance limit and express in form of the normalized value defined by the following definition (see Table 3.6 for results):

$$C(k) = \frac{TPOP(k)}{\sum_{j \in N1} TPOP(j)} \tag{3.2}$$

where C(k) is the attractive value of potential site k, TPOP (k) is number of population within the 5 km radius and N1 is set of the chosen potential sites.

(3) Determine attractiveness values for each chosen existing schools based on the number of application (at US level) per seat defined by (see Table 3.6 for results):

$$C(k) = \frac{AP(k)}{\sum_{j \in N2} AP(j)} \tag{3.3}$$

where C(k) is attractive value of selected school k, AP(k) is number of applications (at US level) per available seat of school k, and N2 is set of the chosen existing schools.

It is assumed that number of potential students (age 15-17) of village i [call Q(i,j)] are contributed to a chosen potential school j in according with the following relation:

$$Q(i,k) = R(i,k) \times POT(i) \tag{3.4}$$

where POT(i) is the potential students living at village i, R(i,k) is the contributing weight defined by the following formula:

$$R(i,k) = \frac{\left(\frac{C(k)}{D(i,k)^2}\right)}{\sum_{j \in P}\left(\frac{C(j)}{D(i,j)^2}\right)} = \frac{CD(i,k)}{\sum_{j \in P} CD(i,j)} \tag{3.5}$$

which makes R = 0-1., C is the school's attractiveness value defined by Eqs. 3.2 and 3.3, D(i,j) is the travel distance from village i to site j, and P is set of needed school sites.

As a consequence, total travel distance (TD) can be estimated using the following relation (M is set of the villages),

$$TD = \sum_{i\in M}\sum_{k\in P} Q(i,k)\times D(i,k) = \sum_{i\in M}\sum_{k\in P} R(i,k)\times W(i)\times D(i,k) = \sum_{i\in M}\sum_{k\in P} R(i,k)\times DW(i,k)$$

$$TD = \sum_{i\in M}\sum_{k\in P} \frac{CD(i,k)\times DW(i,k)}{\sum_{j\in P} CD(i,j)} = \sum_{i\in M}\sum_{k\in P} \frac{CDW(i,k)}{\sum_{j\in P} CD(i,j)} \quad (3.6)$$

Table 3.6 Data of C values for all 59 potential sites (calculated from Eqs. 3.2-3.3).

Site	Not-existing school			Site	Not-existing school		
	Name	DIST	C		Name	DIST	C
1	ต.บางภาษี	TB3	0.06	32	ต.บ้านใหม่	TS1	0.12
2	ต.บางปลา	TB4	0.14	33	ต.บางช้าง	TS2	0.09
3	ต.บางระกำ	TB5	0.05	34	ต.บางกระทึก	TS3	0.09
4	ต.บางไทรป่า	TB6	0.17	35	ต.บางเตย	TS4	0.11
5	ต.ดอนตูม	TB8	0.09	36	ต.หอมเกร็ด	TS5	0.08
6	ต.หินมูล	TB9	0.13	37	ต.คลองใหม่	TS7	0.07
7	ต.คลองนกกระทุง	TB10	0.12	38	ต.กระทุ่มล้ม	TS8	0.08
8	ต.นราภิรมย์	TB12	0.05	39	ต.อ้อมใหญ่	TS9	0.10
9	ต.นิลเพชร	TB13	0.06	40	ต.สามพราน	TS11	0.09
10	ต.ไผ่หูช้าง	TB14	0.06	41	ต.ทรงคนอง	TS12	0.02
11	ต.ไทรงาม	TB15	0.06	42	ต.ตลาดจินดา	TS13	0.02
12	ต.บางแก้วฟ้า	TN2	0.03	43	ต.ท่าข้าม	TS14	0.12
13	ต.บางกระเบา	TN3	0.12	Site	Existing school		
14	ต.บางพระ	TN4	0.04		Name	SCH	C
15	ต.บางระกำ	TN5	0.03	1	บางเลนวิทยา	SB5	0.61
16	ต.ดอนแฝก	TN6	0.03	2	บางหลวงวิทยา	SB12	0.11
17	ต.ห้วยพลู	TN7	0.05	3	บัวปากท่าวิทยา	SB31	0.22
18	ต.โคกพระเจดีย์	TN8	0.02	4	สถาพรวิทยา	SB41	0.06
19	ต.ขุนแก้ว	TN9	0.07	5	ปรกแก้ววิทยา	SN1	0.02
20	ต.ลานตากฟ้า	TN11	0.02	6	แหลมบัววิทยา	SN17	0.14
21	ต.พะเนียด	TN14	0.06	7	เพิ่มวิทยา	SN21	0.05
22	ต.ท่ากระชับ	TN15	0.08	8	จิ้วรายบุญมีรังสฤษดิ์	SN22	0.24
23	ต.ท่าตำหนัก	TN17	0.10	9	พลอยจาตุรจินดา	SN27	0.05
24	ต.ไทยาวาส	TN18	0.06	10	ภัทรญาณวิทยา	SN36	0.50
25	ต.สัมปทวน	TN19	0.07	11	ปรีดารามวิทยาคม	SS15	0.08

Table 3.6 Data of C values for all 59 potential sites (calculated from Eqs. 3.2-3.3) (Continued).

Site	Not-existing school			Site	Existing school		
	Name	DIST	C		Name	SCH	C
26	ต.ศีรษะทอง	TN20	0.08	12	วัดไร่ขิงวิทยา	SS27	0.53
27	ต.ศรีมหาโพธิ์	TN21	0.05	13	ภ.ป.ร.ราชวิทยาลัยฯ	SS38	0.22
28	ต.วัดละมุด	TN23	0.05	14	สามพรานวิทยา	SS40	0.17
29	ต.วัดสำโรง	TN24	0.03	15	รัตนโกสินทร์สมโภชฯ	SP9	0.49
30	ต.คลองโยง	TP1	0.52	16	กาญจนาภิเษกวิทยาลัย	SP10	0.51
31	ต.มหาสวัสดิ์	TP2	0.48	-	-	-	-

(4) Produce ideal US school location map (for each district) that gives minimum value of the total travel distance to school using the gravity p-median model (concept of this model is described in Chapter II).

(5) Consider efficiency of the chosen school sites from (4) in terms of average travel distance and compare with those obtained from idealized and p-median scenarios.

It should be noted here that, for the calculation of travel distance, the criteria of students attending the closest schools is not applicable to the gravity p-median scenario. This is because, in the model's simulation, each student can attend any available schools of their interest regardless of the travel distance (as described in Eq.3.6). And this can result in the significantly higher average travel distance to school of the students.

(6) Perform steps (1)-(4) using population data of year 2015 and 2020, and compare results with those of year 2007.

3.3 Determination on Ideal Numbers of School

In principle, to maximize school planning and managing efficiency in term of the service area, the no-service and overlapped areas should be minimum. This objective can be achieved if number of the servicing schools (at each level) is not too high (to reduce the running cost), and the proposed school service area should not be too low (to provide high percentage coverage of total service area). Theoretically, the ideal number of needed schools can be determined based on knowledge of total study area and a defined service area of individual school. In theory, the ideal service area that provides least overlapping area should have a hexagonal shape (Hallak, 1977), from which for a given radius R, the service area (SA) of a school could be readily identified using relationship $SA = 2.598R^2$. This makes sizes of the service area for R = 1, 2, 3, 4, 5, 7 and 10 km become 2.60, 10.39, 23.38, 41.47, 64.95, 127.30, and 259.8 km^2, respectively (as shown in Table 3.7).

Table 3.7 Ideal numbers of schools (based on the idealized hexagonal service area).

District	School's service area at different service radii (in km^2)						
	1 km (2.60)	**2 km (10.39)**	**3 km (23.38)**	**4 km (41.57)**	**5 km (64.95)**	**7 km (127.3)**	**10 km (259.8)**
BLN	221.30	55.32	24.59	13.83	8.85	4.52	2.21
NCS	102.21	25.55	11.36	6.39	4.09	2.09	1.02
PMT	27.73	6.93	3.08	1.73	1.11	0.57	0.28
SPR	87.26	21.81	9.70	5.45	3.49	1.78	0.87
Total	438.49	109.62	48.72	27.40	17.54	8.95	4.38

For schools that provide education only at primary level, the increase of proposed service radius from 1 to 3 km means 9-fold expansion of its total service

area. This would dramatically reduce demand for the primary schools to serve most villages locating in the area. Table 3.7 indicates that, it should be only about 49 primary schools which are well-placed geographically (at 3km service radius) required to serve the entire area. However, the number of 50 is preferred in this study (instead of the original number of 49) where the extra 1 school is added to support possible excess number of P-level (or LS-level) students that are required to attend schools each year. But if the service radii of 1 or 2 km are applied, numbers of the preferred schools (under these situations) are about 440 and 110 respectively. This means with 1km-radius criteria (with hexagonal shape), more than 300 new schools is required to serve this area (only) at this level. This is very unlikely to be succeeded. However, at 2 km radius, number of the required P school is comparable to the existing one (110 and 129). On the contrary, under the given criteria of 3km-radius, number of the ideal primary schools can be reduced by about 60% of the present number (from 127 to about 50), which has more opportunity to be fulfilled. However, great reduction on the number of functioning schools might lead to more no-service area if the overlapping area is still relatively high.

In case of the lower and upper secondary levels, numbers of the preferred schools under the criteria of 3, 5, and 7 km service radii are about 50, 18, and 9, respectively. This means if the 3 km criterion is imposed, number of the suggested ideal schools for LS level will be slightly higher than that of the existing one (39) but if 5 km criterion is enforced, this number will decrease to about 18 and, in this case, substantial number of the present LS schools might be able to be dissolved or merged with some other larger school nearby to reduce running cost of doing service at this level. For the US level, if the 5 km criterion is imposed, number of the ideal schools

will be about 18, which is similar to that of the existing US schools (16). But if the 7 km criterion is applied, this number will decrease to about 9 only. This can make several of the present US schools become redundant but the no-service areas may increase if the functioning schools are not properly placed.

As a consequence, if the state's policy of applying 3 km service area to P and LS schools and 5 km for US school are fully enforced in the area, ideal number of the schools needed at these levels will be about 50, 50, and 18, respectively (under hexagonal shape). If compare to present situation (same level), number of the existing P-level schools must be dropped dramatically (from current 127 to about 50) whereas numbers of existing LS and US schools (39 and 16) are rather similar to that of the ideal ones (50 and 18).

Therefore, the noticeably change in their preferred numbers might be not much required (unlike for the P level) but the relocation, or dissolving, of some small schools to provide higher efficiency in term of the service area may still be necessary. However, it is crucial to emphasize here that all these numbers were come up under assumption that a school's service area has a hexagonal shape (at different radii) which is not exactly true in the actual analysis (where a service area is determined by the prescribed distance limit along the road network). But these numbers are still practical for general use in this study as they represent the ideal scenarios that were interested in.

3.4 Database Construction Process

As stated earlier, the first objective of this thesis is to develop GIS database necessary for further study. The data were acquired from 3 main sources: (1) responsible agencies, (2) internet, and (3) field surveys, and can be separated into 3

(1) General data of the area; e.g. road network map or administrative map.

(2) School data; e.g. location, official name, or number of students and teachers.

(3) Tambon/village data; e.g. location, area cover, and number of population.

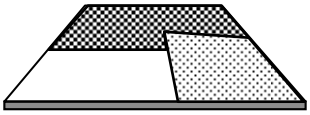
Detailed process of the database construction is as follows:

Assemble interested data from the responsible sources. These data were then categorized into 6 broad groups to be stored in the database as listed in Table 3.8. Details of the associated attribute data included in each mentioned data category are described in Table 3.9a-3.9f, respectively.

Table 3.8 List of 6 broad groups of data contained in the constructed database.

Data category	Format	Data description
Administrative/Amphoe	polygon	General data at district level (as stated in Table 3.9a)
Administrative/Tambon	polygon	General data at sub-district level (as stated in Table 3.9b)
Road Network	line	General data of used road network (as stated in Table 3.9c)
School Data	point	General data of the studied schools (as stated in Table 3.9d)
Village Data	point	General data of the studied villages (as stated in Table 3.9e)
Tambon Data	point	General data of the studied sub-districts (as stated in Table 3.9f)

Table 3.9a Details of the attribute data included in the Administrative/Amphoe category.

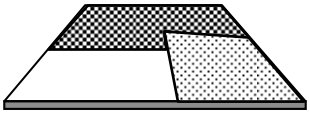


Shape Name:	Npt 2 gis
Feature Class:	Polygon
Data Source:	Department of Provincial Administration (DPA) (2009)
Scale:	1:50,000
Projected Coordinate System:	WGS84/UTM zone 47N

Data File	Attribute	Description	
Npt 2 gis	FID *	Polygon identification code	รหัสของ polygon
	Shape *	Data type	ชนิดข้อมูล
	AREA *	Polygon area	ขนาดพื้นที่ของ polygon (ตารางเมตร)
	PERIMETER *	Polygon perimeter	เส้นรอบรูปของ polygon (เมตร)
	AMPHOE_ *	Programming code	รหัสภายในของโปรแกรม
	AMPHOE_ID	User-defined identification code	รหัสโดยผู้ใช้โปรแกรม
	AMPHOE_IDN	District identification code	รหัสอำเภอ
	AMPHOE_E	District name (in English)	ชื่ออำเภอภาษาอังกฤษ
	AMPHOE_T	District name (in Thai)	ชื่ออำเภอภาษาไทย
	PROV_CODE	Province code	รหัสจังหวัด
	AMP_CODE	District code	รหัสอำเภอ
	PROVINCE_E	Province name (in English)	ชื่อจังหวัดภาษาอังกฤษ
	PROVINCE_T	Province name (in Thai)	ชื่อจังหวัดภาษาไทย

* Standard values set by the operating system.

Table 3.9b Details of the attribute data included in the Administrative/Tambon category.

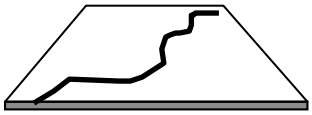


Shape Name: Npt 2 gis
Feature Class: Polygon
Data Source: Department of Provincial Administration (DPA) (2009)
Scale: 1: 50,000
Projected Coordinate System: WGS84/UTM zone 47N

Data File	Attribute	Description	
Npt 2 gis	FID *	Polygon identification code	รหัสของ polygon
	Shape *	Data type	ชนิดข้อมูล
	AREA *	Polygon area	ขนาดพื้นที่ของ polygon (ตารางเมตร)
	PERIMETER *	Polygon perimeter	เส้นรอบรูปของ polygon (เมตร)
	Tam _ *	Programming code	รหัสภายในของโปรแกรม
	Tam_ID	User-defined identification code	รหัสโดยผู้ใช้โปรแกรม
	Tambon_E	Tambon name (in English)	ชื่อตำบล (ภาษาอังกฤษ)
	Tambon_T	Tambon name (in Thai)	ชื่อตำบล (ภาษาไทย)
	AMPHOE_IDN	District identification code	รหัสอำเภอ
	AMPHOE_E	District name (in English)	ชื่ออำเภอภาษาอังกฤษ
	AMPHOE_T	District name (in Thai)	ชื่ออำเภอภาษาไทย
	PROV_CODE	Province code	รหัสจังหวัด
	AMP_CODE	District code	รหัสอำเภอ
	PROVINCE_E	Province name (in English)	ชื่อจังหวัดภาษาอังกฤษ
	PROVINCE_T	Province name (in Thai)	ชื่อจังหวัดภาษาไทย

* Standard values set by the operating system.

Table 3.9c Details of the attribute data included in the Road Network category.



Shape Name:	Road network
Feature Class:	Line
Data Source:	City Planning Department (CPD) (2009)
Scale:	1:50,000
Projected Coordinate System:	WGS84/UTM zone 47N

Data File	Attribute	Description	
Road network	FID *	Line identification code	รหัสของ line
	Shape *	Data type	ชนิดข้อมูล
	FNODE_ *	Programming code for the starting point	รหัสภายในของโปรแกรมแสดงจุดเริ่มต้น
	TNODE_ *	Programming code for the terminating point	รหัสภายในของโปรแกรมแสดงจุดสิ้นสุด
	LPOLY_ *	Polygon number (left side)	เลข polygon ด้านซ้าย
	RPOLY_ *	Polygon number (right side)	เลข polygon ด้านขวา
	LENGTH *	Line length	ความยาวของเส้น
	ROADCL_ *	Programming code	รหัสภายในของโปรแกรม
	ROADCL_ID	User-defined identification code	รหัสโดยผู้ใช้โปรแกรม
	RC_LNUM	Road number	หมายเลขถนน
	RC_HWTYPE	Road type	ประเภทเส้นทาง
	DESC_	Description of road type	คำอธิบายประเภทเส้นทาง

* Standard values set by the operating system.

Table 3.9d Details of the attribute data included in the School Data category.



Shape Name:	School data
Feature Class:	Point
Data Source:	Education Service Area Office 2 (2007) and field surveys
Scale:	1: 50,000
Projected Coordinate System:	WGS84 /UTM zone 47N

Data File	Attribute	Description	
School data	FID *	Point identification code	รหัสของ point
	Shape *	Data type	ชนิดข้อมูล
	X	X-coordinate of a point	พิกัดตำแหน่ง X ของ point
	Y	Y-coordinate of a point	พิกัดตำแหน่ง Y ของ point
	School id	User-defined identification code	รหัสโดยผู้ใช้โปรแกรม
	School code	School code	รหัสโรงเรียน
	School name	School's location name	ชื่อสถานที่ที่ตั้งของโรงเรียน
	Moo	Order of village	ลำดับที่ของหมู่บ้าน
	tambon_id	Tambon identification code	รหัสตำบล
	amphoe_id	District identification code	รหัสอำเภอ
	province_id	Province identification code	รหัสจังหวัด
	boss_name	School's director name	ชื่อผู้บริหาร
	tel	School's telephone number	หมายเลขโทรศัพท์ที่ติดต่อโรงเรียน
	under	School's supervision agency	ภายใต้กำกับการดูแลของหน่วยงาน
	size	School's size	ขนาดของโรงเรียน
	level	Operating education level	ระดับการศึกษาที่เปิดสอน
	room	Number of classroom	จำนวนห้องเรียน
	teacher	Number of teacher	จำนวนครู
	student_ total	Number of total student	จำนวนนักเรียนทั้งหมด

* Standard values set by the operating system.

Table 3.9e Details of the attribute data included in the Village Data category.



Shape Name:	Village data
Feature Class:	Point
Data Source:	Education Service Area Office 2 (2007) and field surveys
Scale:	1: 50,000
Projected Coordinate System:	WGS84 /UTM zone 47N

Data File	Attribute	Description	
Village data	FID *	Point identification code	รหัสของ point
	Shape *	Data type	ชนิดข้อมูล
	CODE	Village code	รหัสหมู่บ้าน
	VILL_NAME	Village name	ชื่อหมู่บ้าน
	CWRAB	Province code	รหัสจังหวัด
	AMPRAB	District code	รหัสอำเภอ
	TMBRAB	Tambon code	รหัสตำบล
	VILLRAB	Village code	รหัสหมู่บ้าน
	CWT_NAME	Province name	ชื่อจังหวัด
	AMP_NAME	District name	ชื่ออำเภอ
	TAM_NAME	Tambon name	ชื่อตำบล
	VILL_NO	Village number	เลขที่หมู่บ้าน

* Standard values set by the operating system.

Table 3.9f Details of the attribute data included in the Tambon Data category.



Shape Name:	Tambon data
Feature Class:	Point
Data Source:	Department of Provincial Administration (DPA) (2009)
Scale:	1: 50,000
Projected Coordinate System:	WGS84 /UTM zone 47N

Data File	Attribute		Description
	FID *	Point identification code	รหัสของ point
	Shape *	Data type	ชนิดข้อมูล
Tambon data	X	X-coordinate of a point	พิกัดตำแหน่ง X ของ point
	Y	Y-coordinate of a point	พิกัดตำแหน่ง Y ของ point
	NAME_T	Tambon's name	ชื่อสถานที่ตั้งของตำบล

The Database Structure

The stated database was constructed using the MySQL programming tool, which is a popular free software that can be operated on the UNIX, OS/2, Mac, and Os or Windows operating systems and can be supported by several common web development platform, e.g., C, C++, JAVA, Perl, Python, and Tci, or ASP. The conceptual structure of the developed database is displayed in Figure 3.3 where in three levels of the operations were created:

(1) Client level-Constructed based on MySQL Client software and chosen Web Development Platform programs.

(2) Application level-Constructed based on the Minnesota Mapserver platform as being local administration GIS Map Server of the system.

(3) Server level-Constructed based on the RDBMS MySQL software.

Results of the study in this part are reported in Section 4.1.

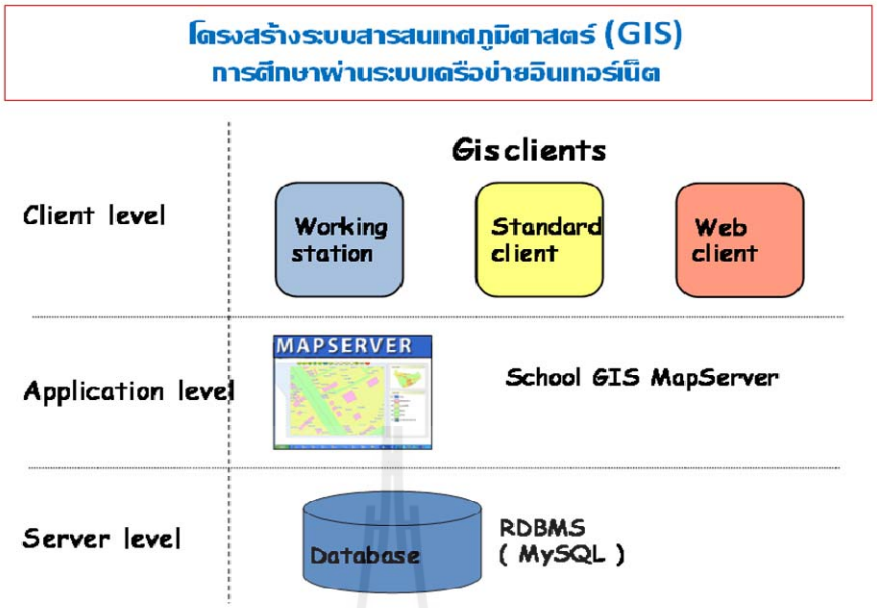


Figure 3.3 The conceptual structure of the developed database (with 3 operating levels).

3.5 Estimation of Future Population

As amounts of population in years 2015 and 2020 are required in this study, the proper method to find their values was executed (at tambon level) based on the relevant records during years 1998-2007 (assuming uniform linear changes during years 1998-2020). In this process, past population annual records of each tambon were plotted with time (year) and assumed to have a simple linear relationship:

$$y = ax + b \tag{3.7}$$

where y is the expected annual population number, x is order of year under consideration (start from 1 for year 1998 and so on, e.g. 10 for year 2007), and a, b are proper constants of the calculation (for each considered tambon). From Eq. 3.7,

population number in years 2015 and 2020 can be estimated by using x = 18 (for year 2015) and 23 (for year 2020) in the equation. For better understanding, case of Nakhon Chai Si District is shown here as an example.

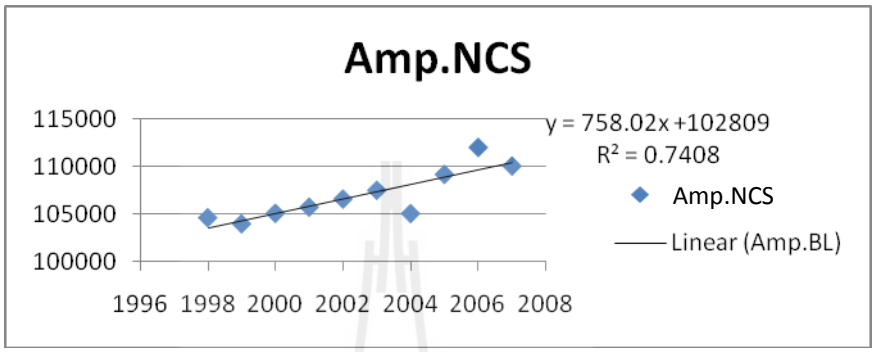


Figure 3.4 Linear relationship of population and years at the Nakhon Chai Si District.

Figure 3.4 illustrates the variation of annual population records with time during 1998-2007 for the Nakhon Chai Si District, from which, the suitable linear relationship to describe this changing pattern was found to be (with $R^2 = 0.7408$):

$$y = 758.02x + 102809 \qquad (3.7)$$

This equation indicates the gradual increase of population number from 1998 to 2007 at rate of about 758 persons per year and the numbers for year 2015 and 2020 can be estimated as being approximately 116,453 and 120,243 persons, respectively.

CHAPTER IV

EFFICIENCY ASSESSMENT FOR PRESENT AND IDEALIZED SCENARIOS

This Chapter presents three main topics of thesis work: (1) result of the database development and population prediction, (2) efficiency assessment of the present school locations, and (3) efficiency assessment of the selected school locations based on the introduced idealized method. Three main aspects on school efficiency (at each school level), were evaluated: service area, service loadings, and travel distance to school as described in Sections 3.2.2 and 3.2.3.

4.1 Outcome of the Database Development and Population Prediction

4.1.1 Database development

In practice, a general client can search for school, or village, data available in the completed database system by entering some searching keywords in the searching area displayed on the User Interface's page of the system (e.g. as seen in Figure 4.1). The valid keywords for searching school data are, for examples, code, name, size, educational level, or name of school's director, and those usable for the village data are village's identification code or name. The general searching algorithm for needed school data is displayed in Figure 4.2.

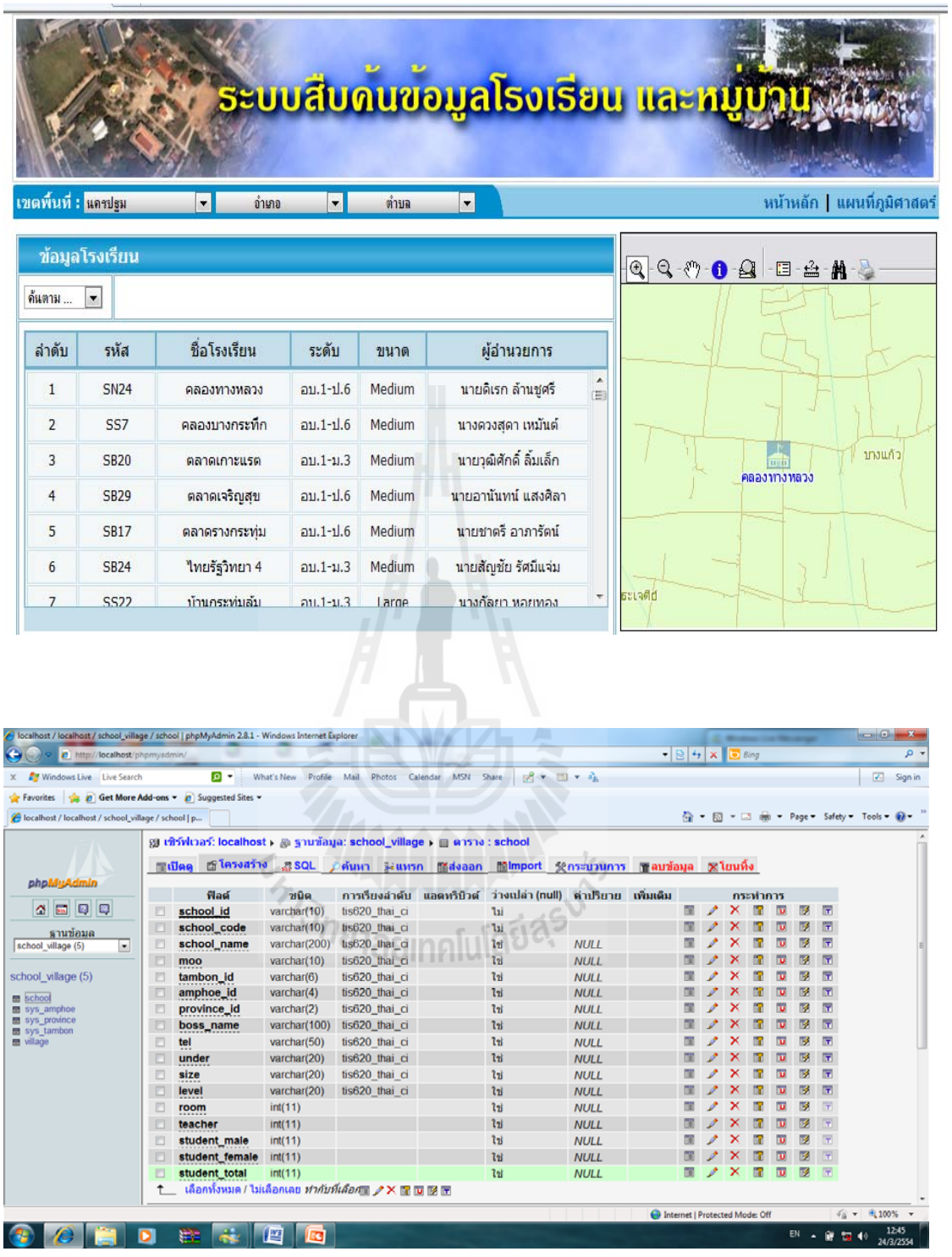


Figure 4.1 User Interface's pages of the constructed database.

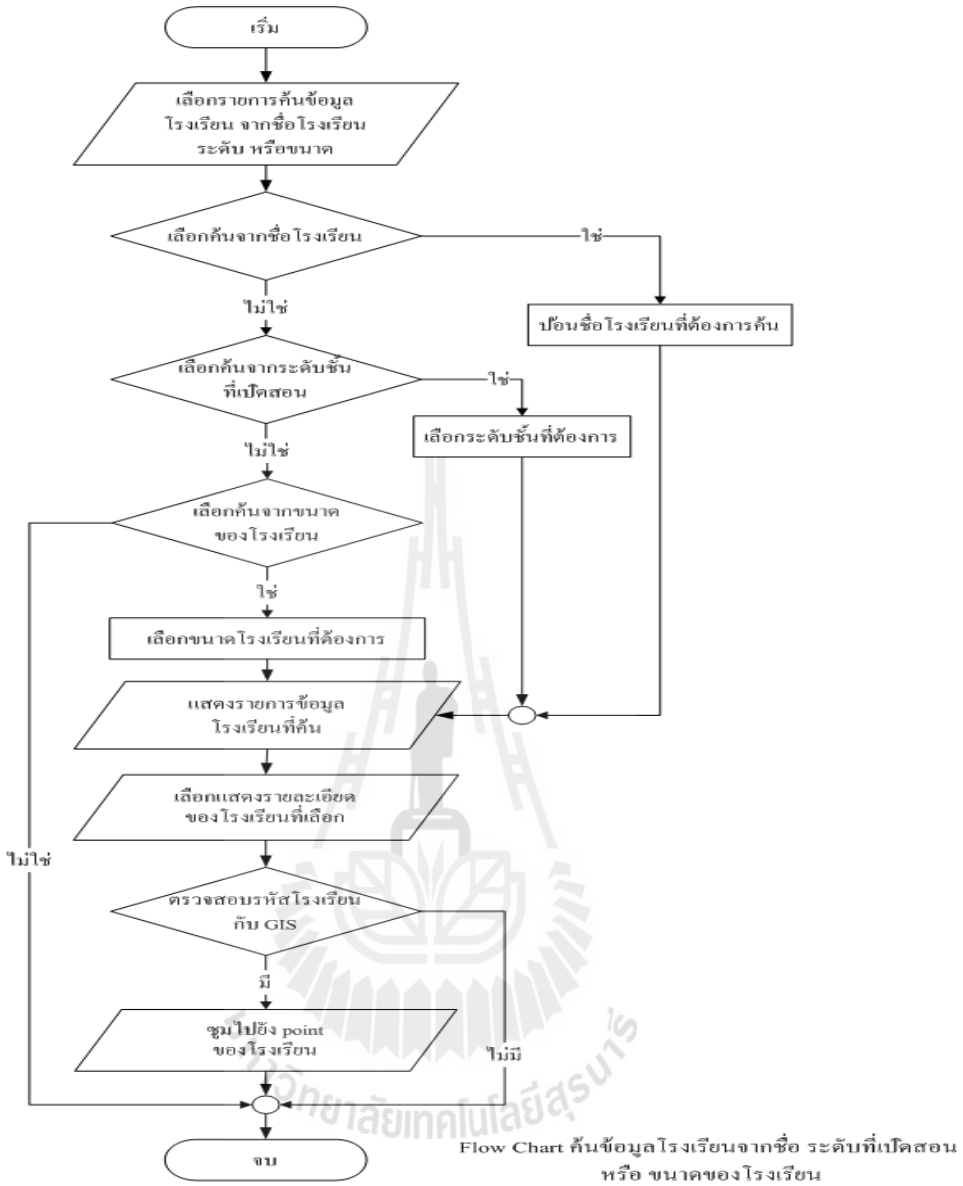


Figure 4.2 General searching algorithm for school data.

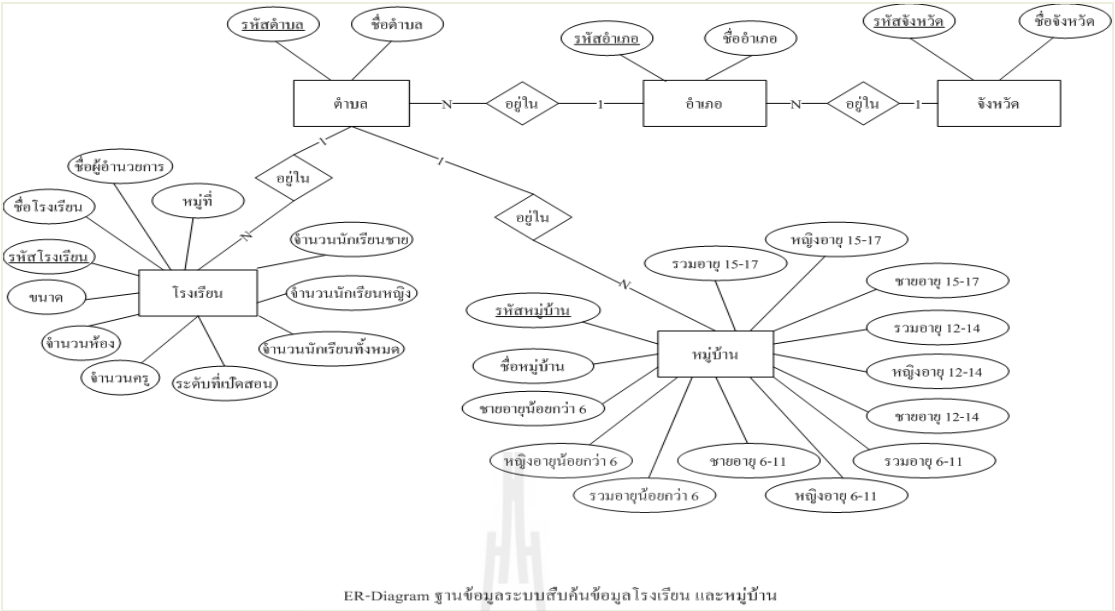


Figure 4.3 Database inner structure showing relations among school, village, and tambon data.

Figure 4.3 illustrates relations of the school, village and tambon data contained in the developed database. These data can be separated into 5 categories as follows:

(1) Province: including province code and name.

(2) District: including district code and name.

(3) Tambon: including tambon code and name.

(4) School: including code, name, director's name, numbers of male and female students, number of total students, size, number of rooms or teachers, school levels.

(5) Villages: including school code, name, numbers of school-aged students (<6 years male/female/total, 6-11 years male/female/total, 12-14 years male/female/total, and 15-17 years male/female/total).

4.1.2 Population prediction

By performing the similar process stated above at all tambons in the study area, their future population in years 2015 and 2020 can be estimated (as shown for examples in Table 4.1 for 16 tambons of the Sma Phran District). From these obtained numbers, along with numbers of years 1998 and 2007, trends of population change at each tambon can be assessed. It was found that, during years 1998-2007, there are only 14 tambons (out of 58) that have numbers of population decreased (mostly in the Bang Len District). The rest have higher number of the population number and distinctively high rise was observed at the Sam Phran District (Table 4.2). In addition, the population density maps for years 1998, 2007, 2015, and 2020 (at tambon level) are displayed in Figure 4.4.

Table 4.1 Population prediction formulas for tambons in Sam Phran District.

Tambon	Prediction formula	Total population			
		1998	2007	2015	2020
Ban Mai	y = 159.27x + 7299.9 R² = 0.9474	7295	8977	10167	10963
Bang Chang	y = 129.39x + 6458.1 R² = 0.9003	6709	7531	8787	9434
Bang Krathuek	y = 149.52x + 7844.7 R² = 0.9853	7970	9325	10536	11284
Bang Toei	y = 14.812x + 3860.3 R² = 0.6075	3878	3953	4127	4201
Hom Kret	y = 172.74x + 6253.1 R² = 0.9813	6457	7863	9362	10226
Khlong Chinda	y = -103.72x + 11167 R² = 0.9332	11051	10232	13034	13553
Khlong Mai	y = 175.09x + 9069.6 R² = 0.5832	8868	9778	12221	13097
Krathum Lom	y = 457.01x + 11558 R² = 0.8934	12683	16106	19784	22069
Om Yai	y = 973.36x + 17189 R² = 0.0938	11943	15399	34709	39576
Rai Khing	y = 524.18x + 15774 R² = 0.7803	17218	21955	25209	27830
Sam Phran	y = 393.37x + 12733 R² = 0.0803	11765	11491	19814	21781
Song Khanong	y = 82.079x + 3077.1 R² = 0.7916	3288	4082	4554	4965
Talat Chinda	y = 57.127x + 6936.6 R² = 0.7866	7137	7671	7965	8251

Table 4.1 Population prediction formulas for tambons in Sam Phran District (Continued).

Tambon	Prediction formula	Total population			
		1998	2007	2015	2020
Tha Kham	y = 136.7x + 8385.9 R^2 = 0.9273	8618	9712	10847	11530
Tha Talat	y = 370.58x + 11031 R^2 = 0.9833	11411	14590	17701	19554
Yai Cha	y = 181.2x + 6274.8 R^2 = 0.9662	6592	8201	9536	10442

Table 4.2 Number of tambons at different population change classes.

District	Period	Population change class (%)					
		-10 to 0	0 to 10	10 to 20	20 to 30	30 to 40	> 40
Bang Len (15 tambons)	1998-2007	8	7	-	-	-	-
	2007-2020	8	5	2	-	-	-
Nakhon Chai Si (24 tambons)	1998-2007	4	16	4	-	-	-
	2007-2020	4	12	7	1	-	-
Phutthamonthon (3 tambons)	1998-2007	-	-	-	-	3	-
	2007-2020	-	-	-	-	-	3
Sam Phran (16 tambons)	1998-2007	2	2	4	8	-	-
	2007-2020	2	1	3	2	6	2
Entire area (58 tambons)	1998-2007	14	25	8	8	3	-
	2007-2020	14	18	12	3	6	5

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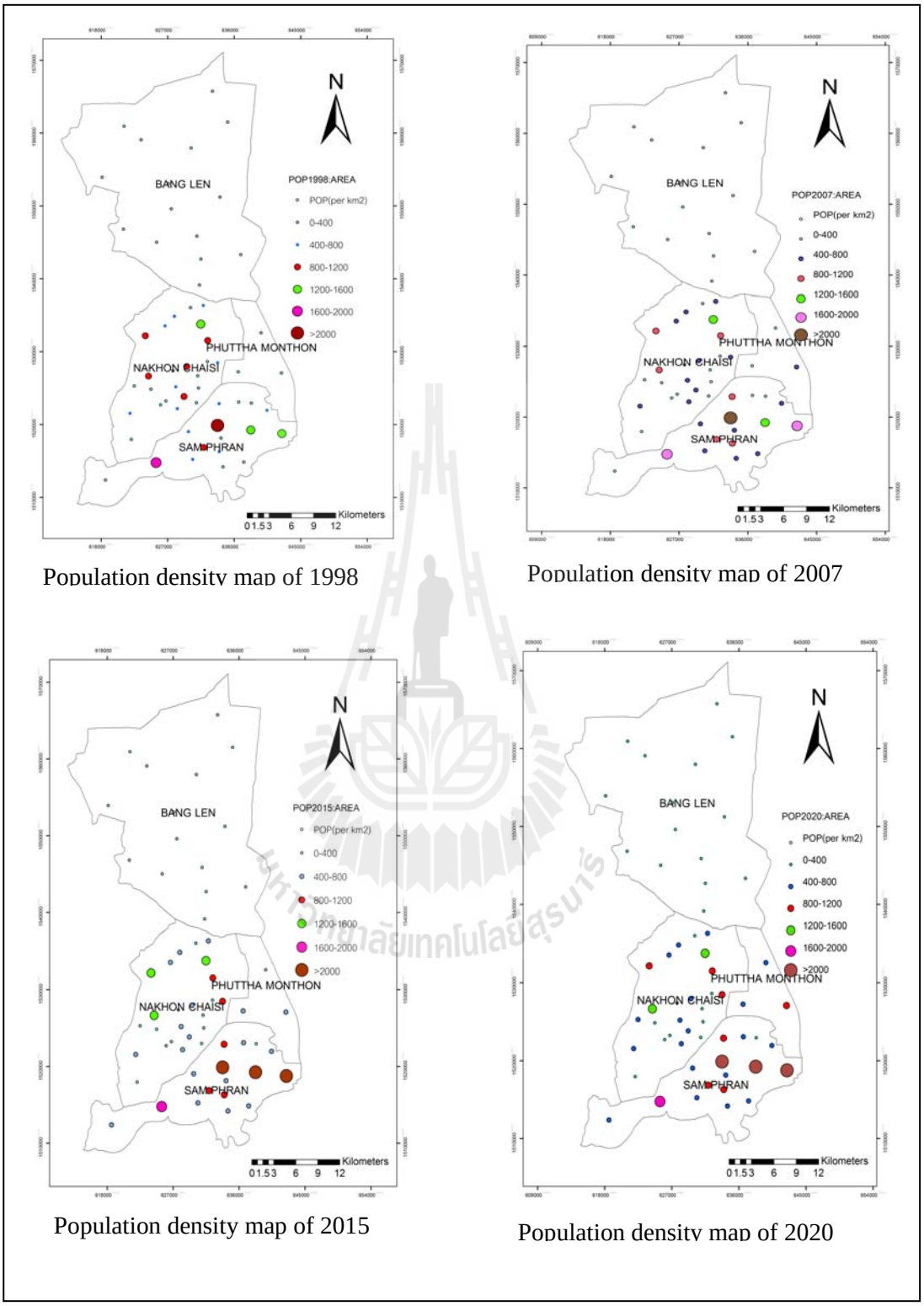


Figure 4.4 Population density maps of years 1998, 2007, 2015, and 2020 (at tambon level).

4.2 Efficiency Assessment of Present School Locations

As detailed in Table 1.2, there were 143 public schools of interest in the academic year 2007, providing formal educations at 3 levels: primary (P), lower-secondary (LS), and upper-secondary (US), distributing over four districts of the study area (Figure 1.2). Among these, 104 schools have only P level, while 23 schools have both P and LS levels, and another 16 schools have both LS and US levels. The Bang Len District had highest number of the referred schools (50) while Phuttamonthon had lowest number (10).

4.2.1 Consideration in term of the service area

In term of the service area, the travel distance limits of 1, 2, 3, 4, 5 km along road network were applied for P level while the distance limits of 3, 5, 7 km, and 5, 7, 10 were applied for the LS and US levels, respectively (Figures 4.6a-4.6e, 4.7a-4.7c, and 4.8a-4.8c).

These numbers were proposed based on the state's policy on school mapping that limit travel distances to school of students to be 3 km at P and LS levels and 5 km at US level, and with recommendation issued by the Council of Educational Facility Planners International (CEFPI) quoted in รัตนา ก่อเกียรติศิริกุล (2521). Distance limits at the P level were selected to represent appropriate modes of the travelling from home to school of students: walking (1-2 km), cycling (2-3 km), and taking motor vehicles (e.g. car, bus, motorcycle) (3-5 km), respectively. Similarly, distance limits for the LS and US levels were chosen to represent cycling and motor vehicle-based travelling modes from home to school (3-5 km for cycling and 5-10 km for taking motor vehicles).

Core assumption for this service-area concept is that each school is responsible to provide educational service only for villages that situate within responsible distance limit of its service area only (regarding to location of the village's center). According to this concept, higher travel distance limit (for a specific school) means more villages that will come under its service. This will lower chances of having no-service area but, in reverse, it shall increase chances of having overlapped service area provided by several schools that locate relatively close to each other.

Table 4.3 and Figure 4.5 illustrate efficiency of existing school locations (at all 3 school levels) in term of service area experienced at village level (under different criteria of travel distance limits) as displayed in Figures 4.6a-4.6e, 4.7a-4.7c, and 4.8a-4.8c. It is obvious that numbers of no-service villages are significantly reduced when distance limits increase. For example, at P level, percentage of no-service village reduces from about 77.43 to 11.6 and 0.23% when the distance limit increases from 1 to 3 and 5 km, respectively (Figures 4.6a, 4.6c, and 4.6e).

However, the expansion of defined service area can greatly produce high amount of the service-overlapping villages; e.g. at P level, percentage of the overlapped village increases from about 0.45 to 49.43 and 94.58 when a distance limit changes from 1 to 3 and 5 km, respectively. Most overlapped villages (at all levels) are under services of 2-5 schools simultaneously but if a distance limit increases, the overlapping service of more than 5 schools is more visible (e.g. at distance limit ≥5 km).

Table 4.3 School efficiency in term of the service area (present situation).

Level	Distance limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (127)	1	343	77.43	98	22.12	2	0.45	-	-
	2	181	40.86	189	42.66	73	16.48	-	-
	3	49	11.06	175	39.50	217	48.98	2	0.45
	4	10	2.26	65	14.67	343	77.43	25	5.64
	5	1	0.23	20	4.51	316	71.33	106	23.93
LS (39)	3	207	46.73	188	42.44	48	10.84	-	-
	5	70	15.80	184	41.53	185	41.76	4	0.90
	7	9	2.03	112	25.28	283	63.88	39	8.80
US (16)	5	239	53.95	127	28.67	77	17.38	-	-
	7	137	30.93	171	38.60	132	29.80	3	0.68
	10	38	8.58	175	39.50	166	37.47	64	14.45

Note: VIL = Number of villages, % ≡ Percent of total villages (443).

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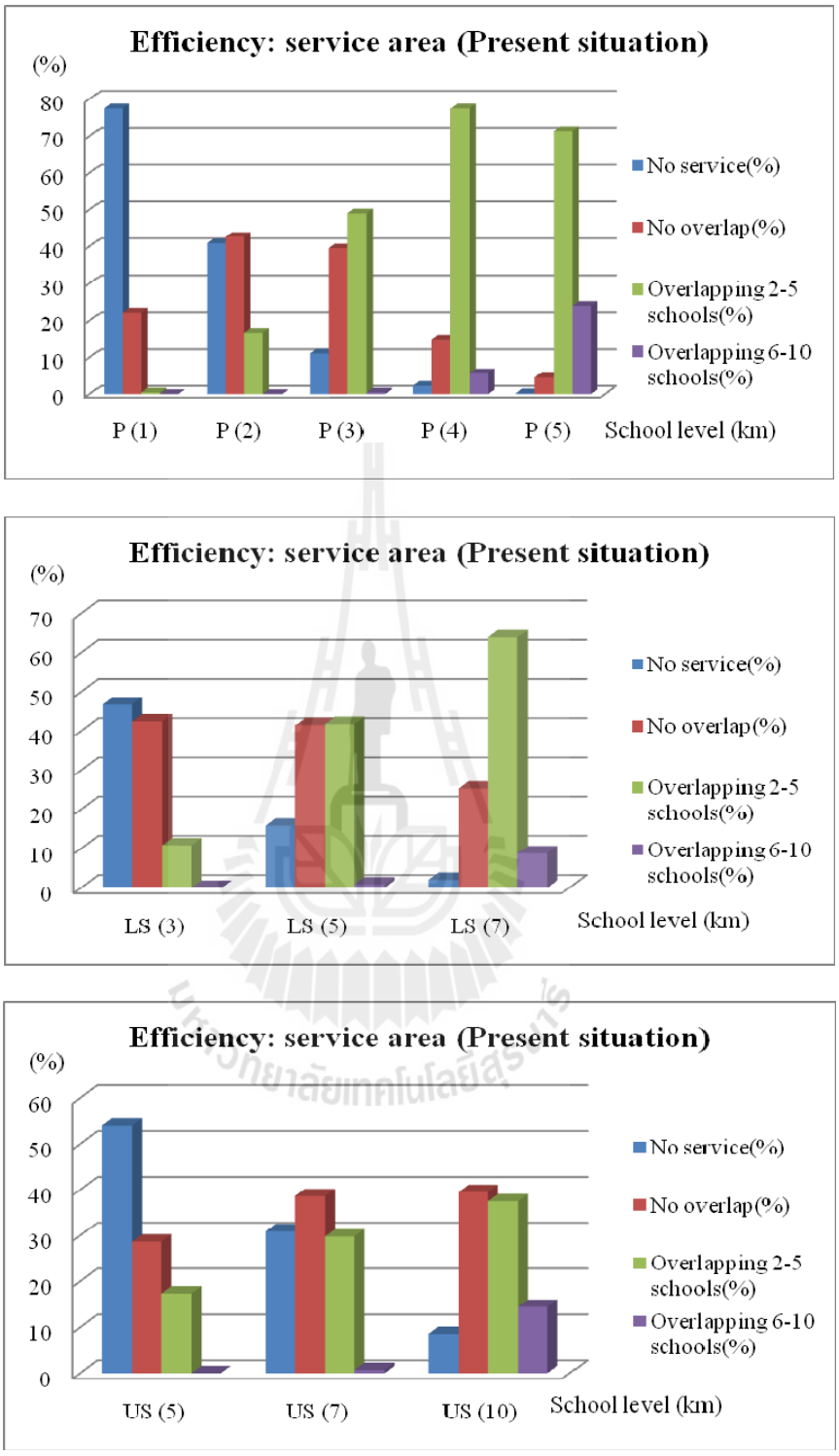


Figure 4.5 School efficiency in term of service area from Table 4.3 (present situation).

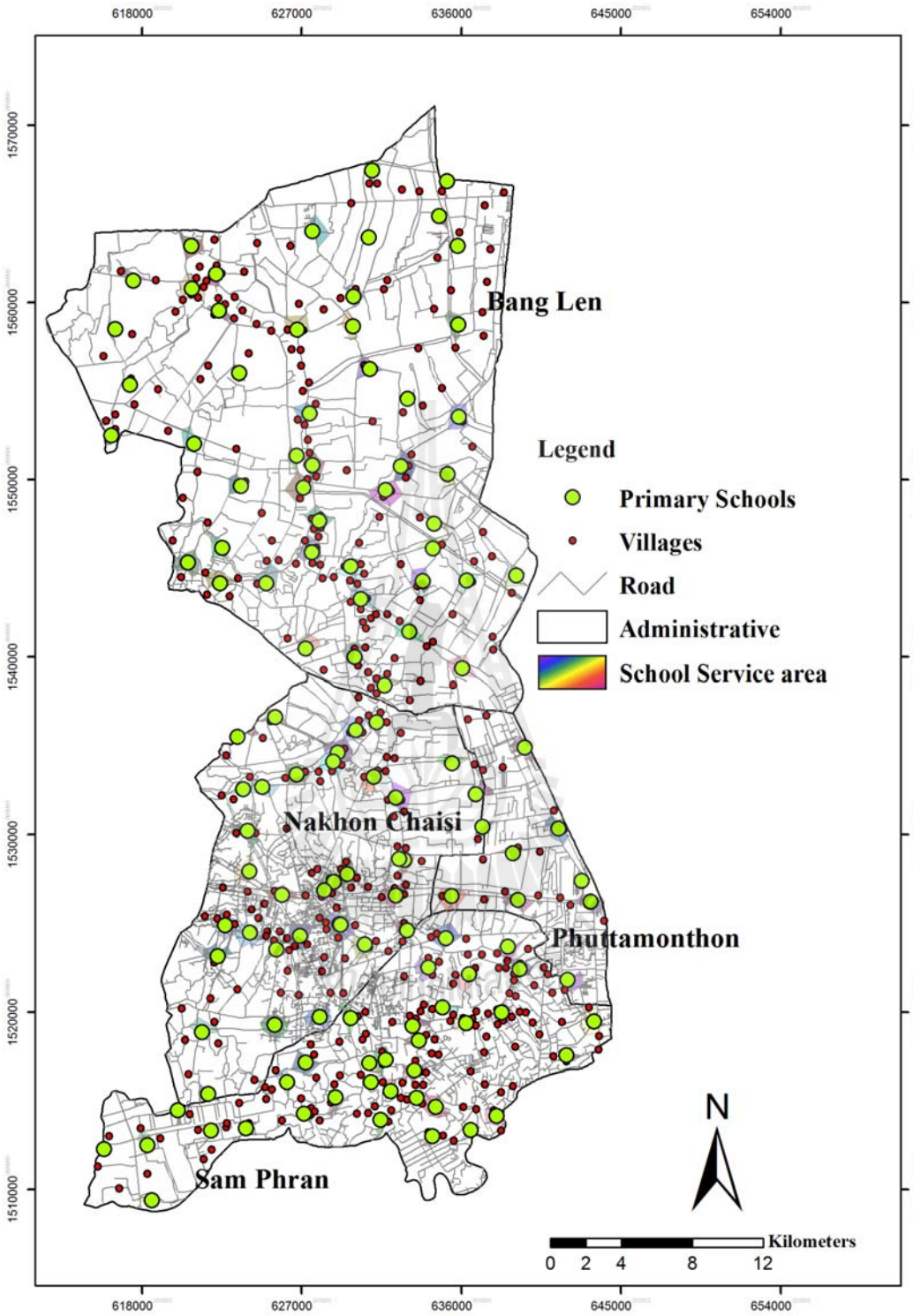


Figure 4.6a Map of the school service areas (1 km limit) at P level (present situation).

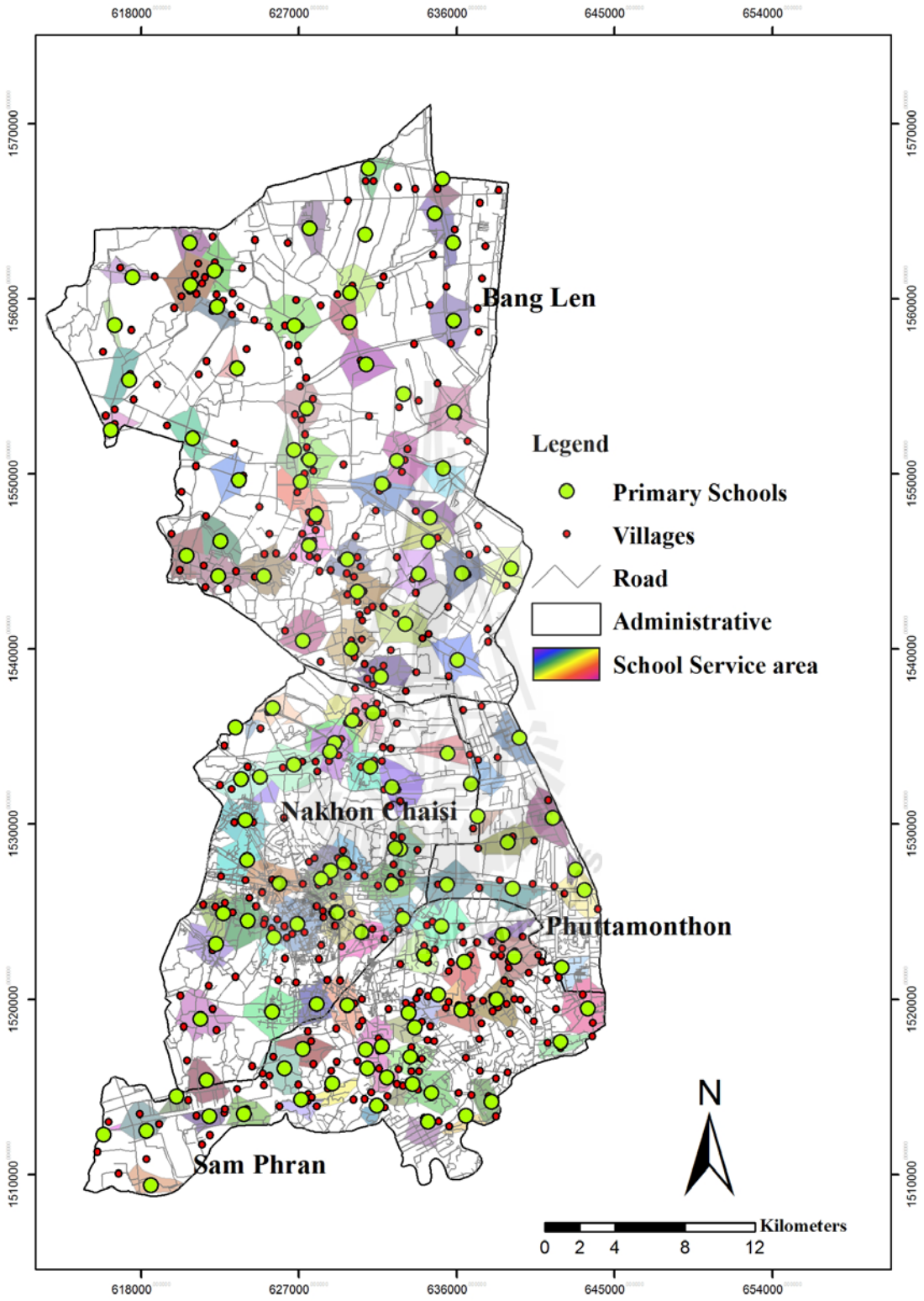


Figure 4.6b Map of the school service areas (2 km limit) at P level (present situation).

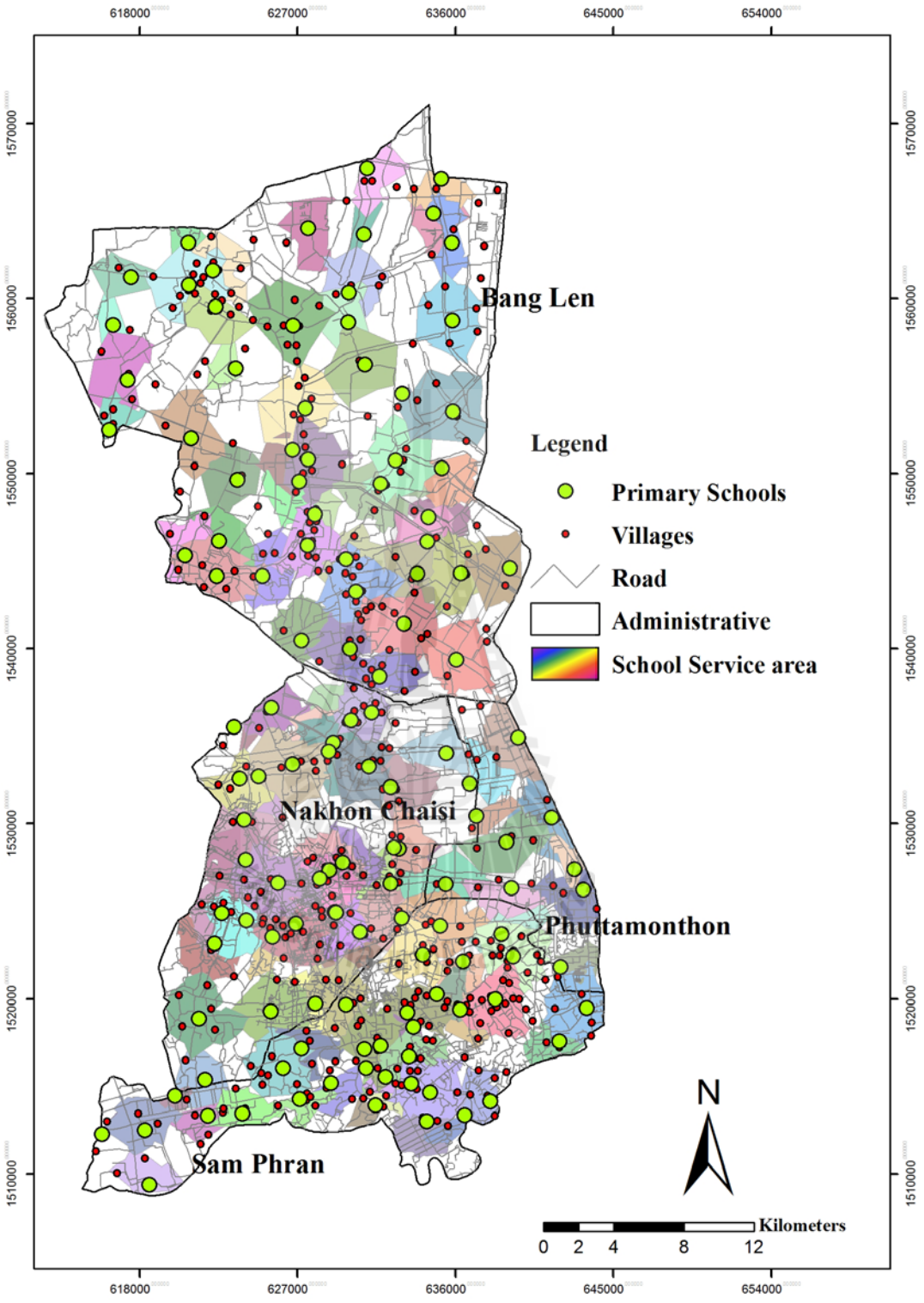


Figure 4.6c Map of the school service areas (3 km limit) at P level (present situation).

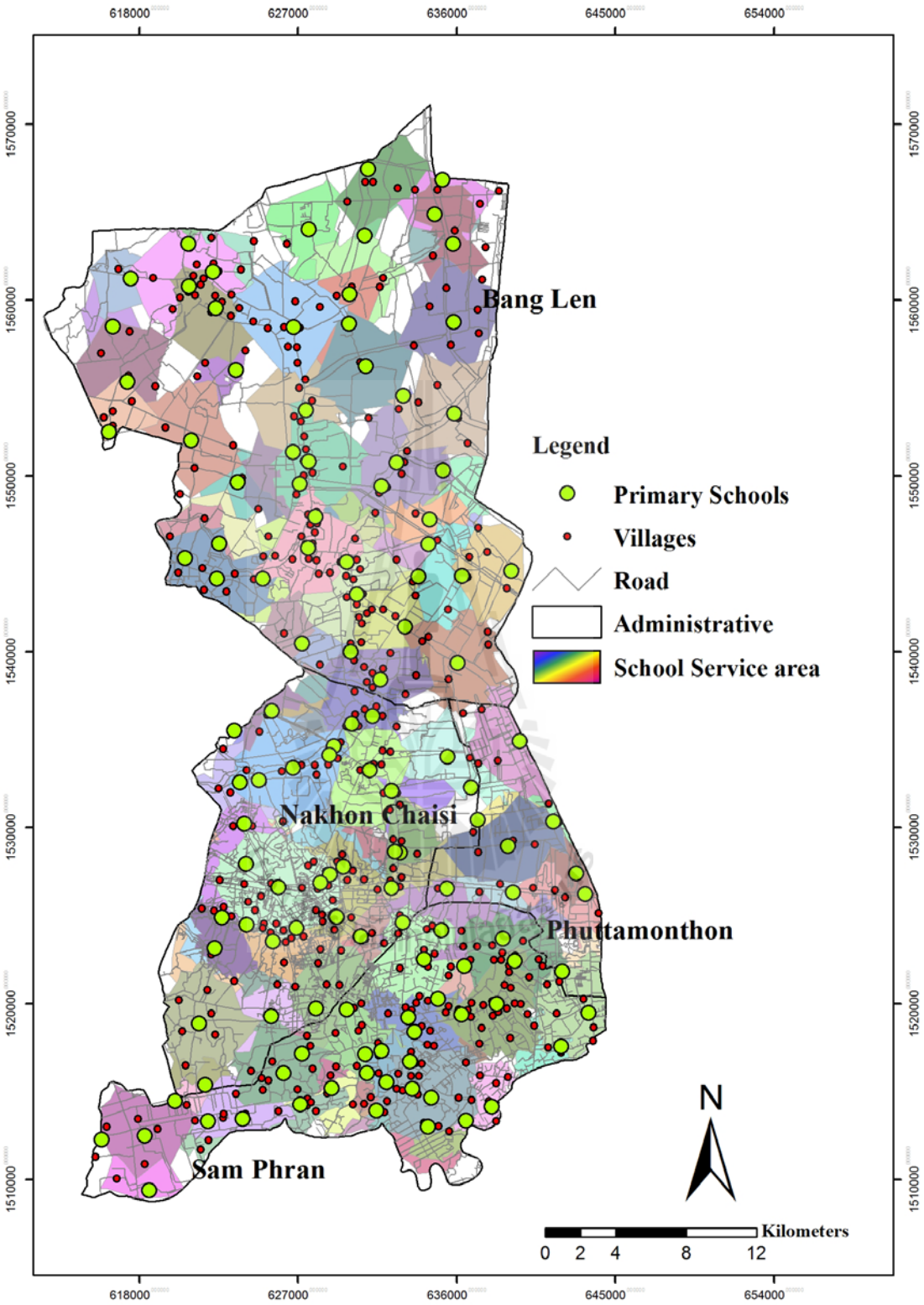


Figure 4.6d Map of the school service areas (4 km limit) at P level (present situation).

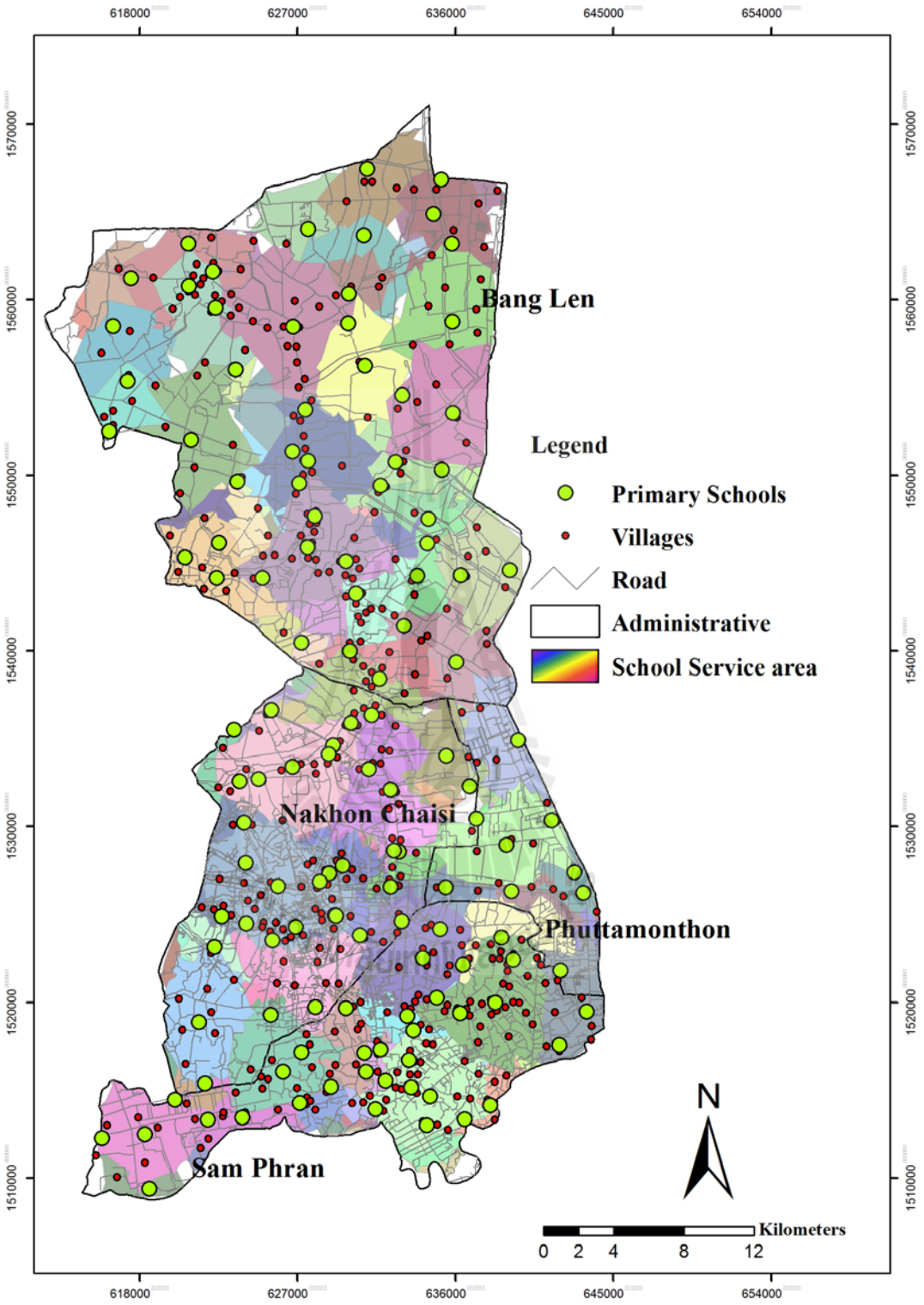


Figure 4.6e Map of the school service areas (5 km limit) at P level (present situation).

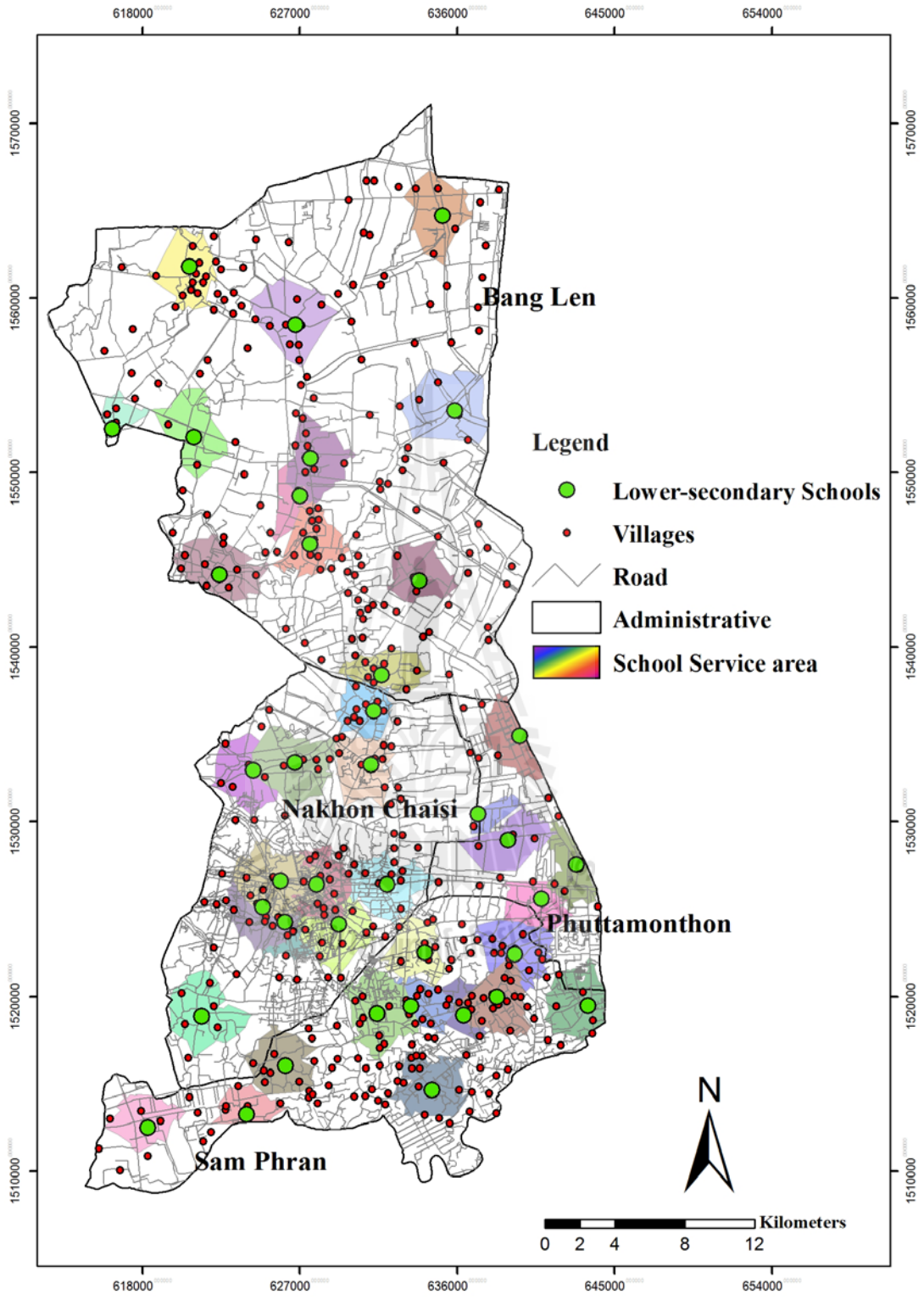


Figure 4.7a Map of the school service areas (3 km limit) at LS level (present situation).

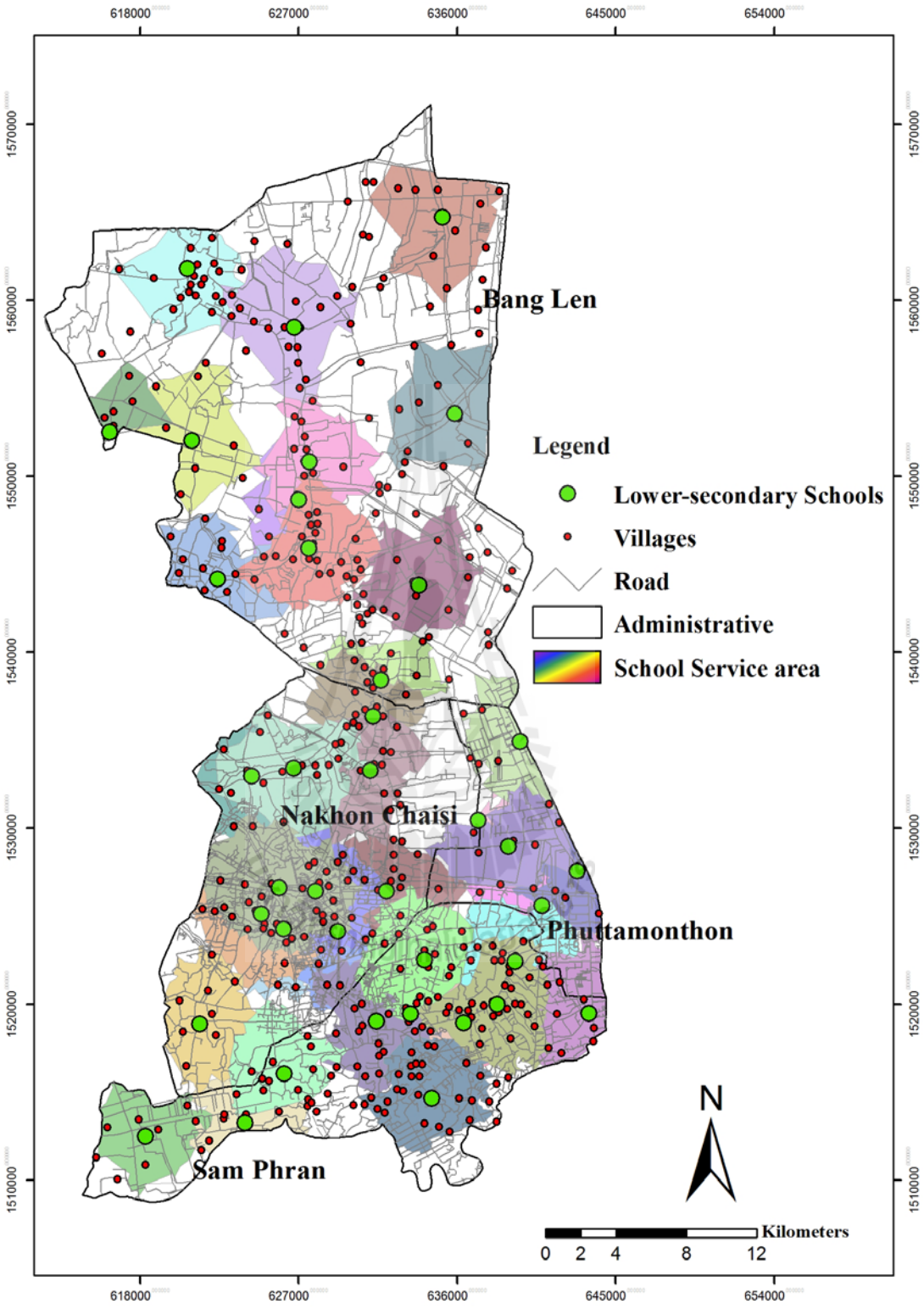


Figure 4.7b Map of the school service areas (5 km limit) at LS level (present situation).

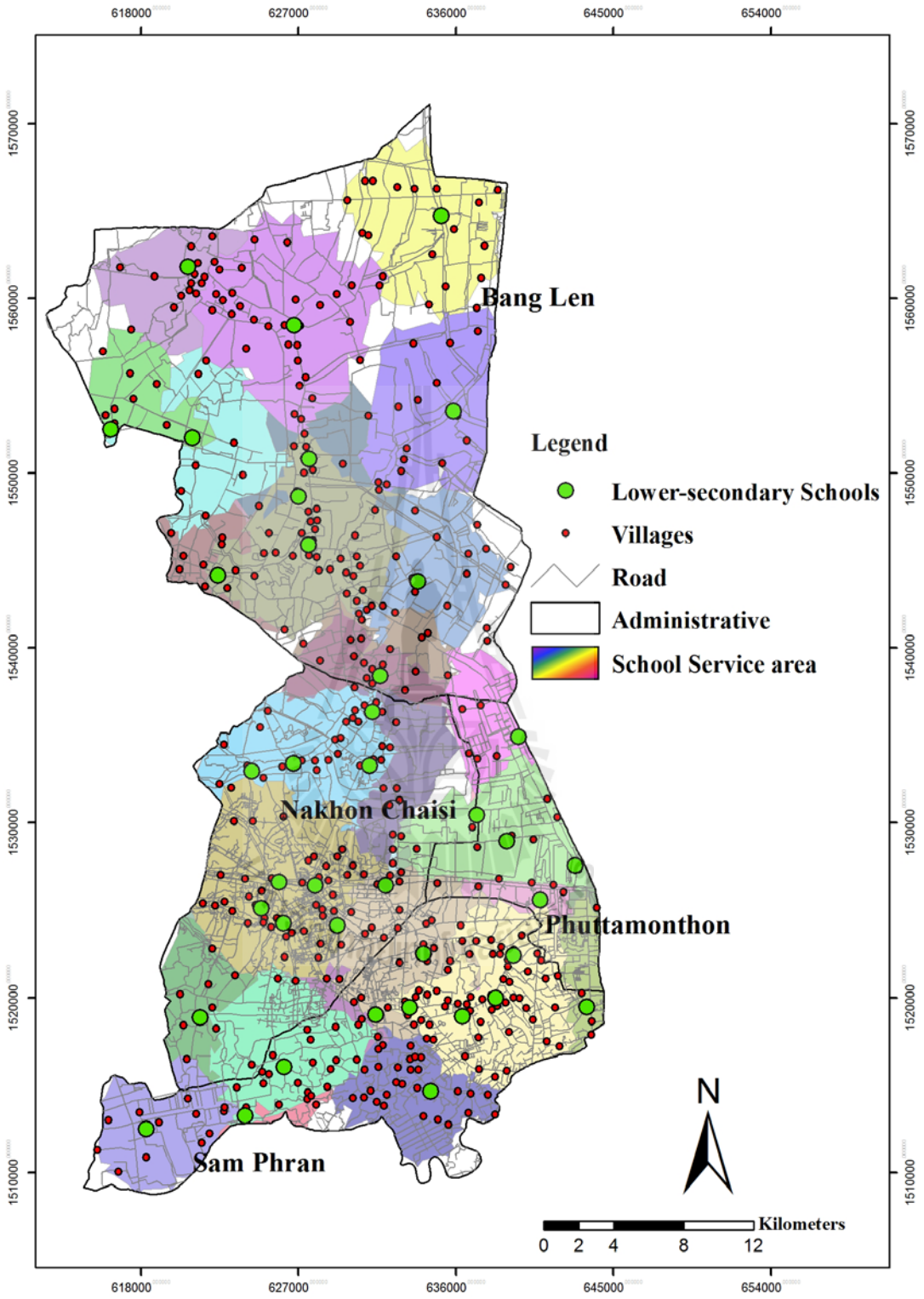


Figure 4.7c Map of the school service areas (7 km limit) at LS level (present situation).

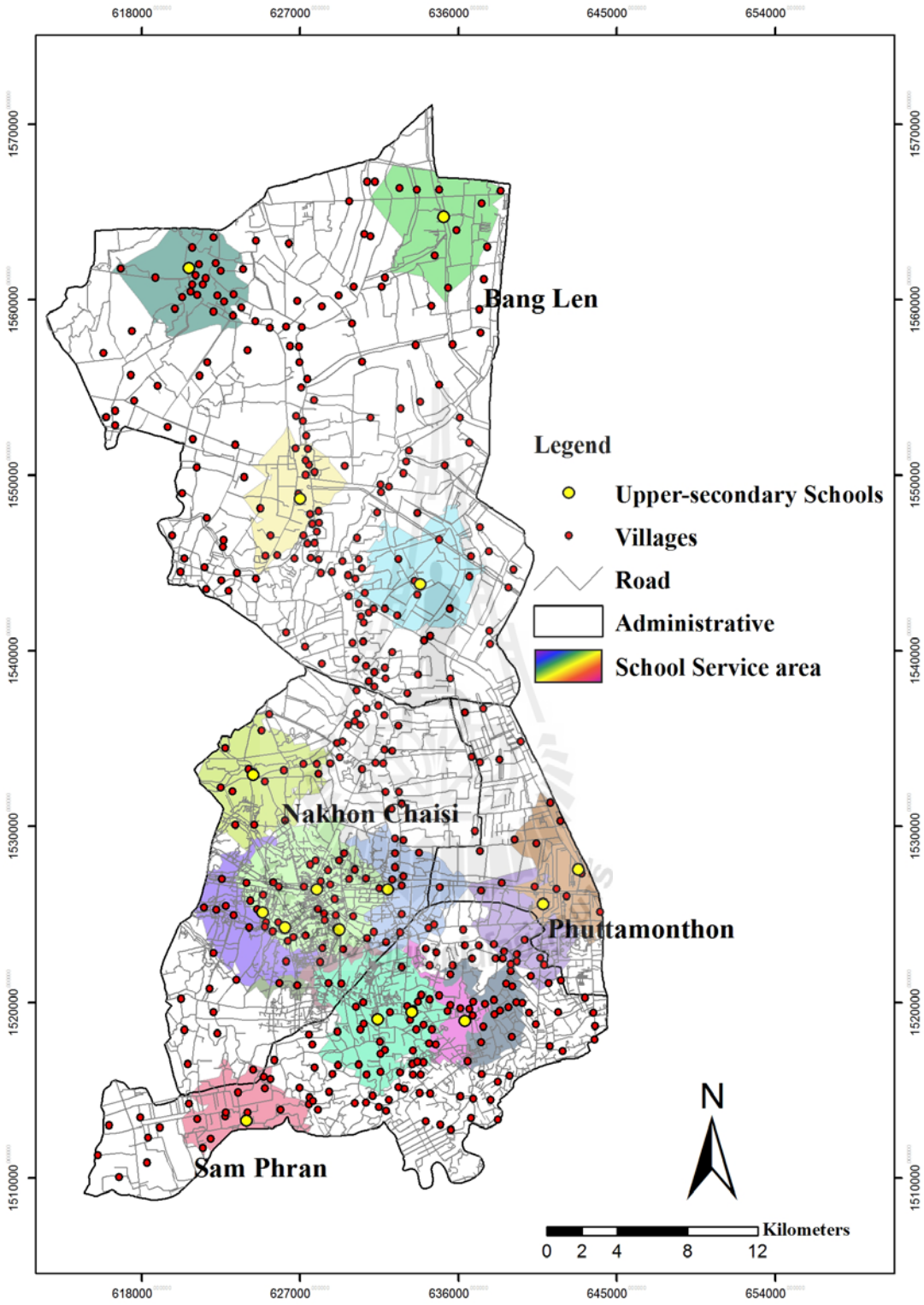


Figure 4.8a Map of the school service areas (5 km limit) at US level (present situation).

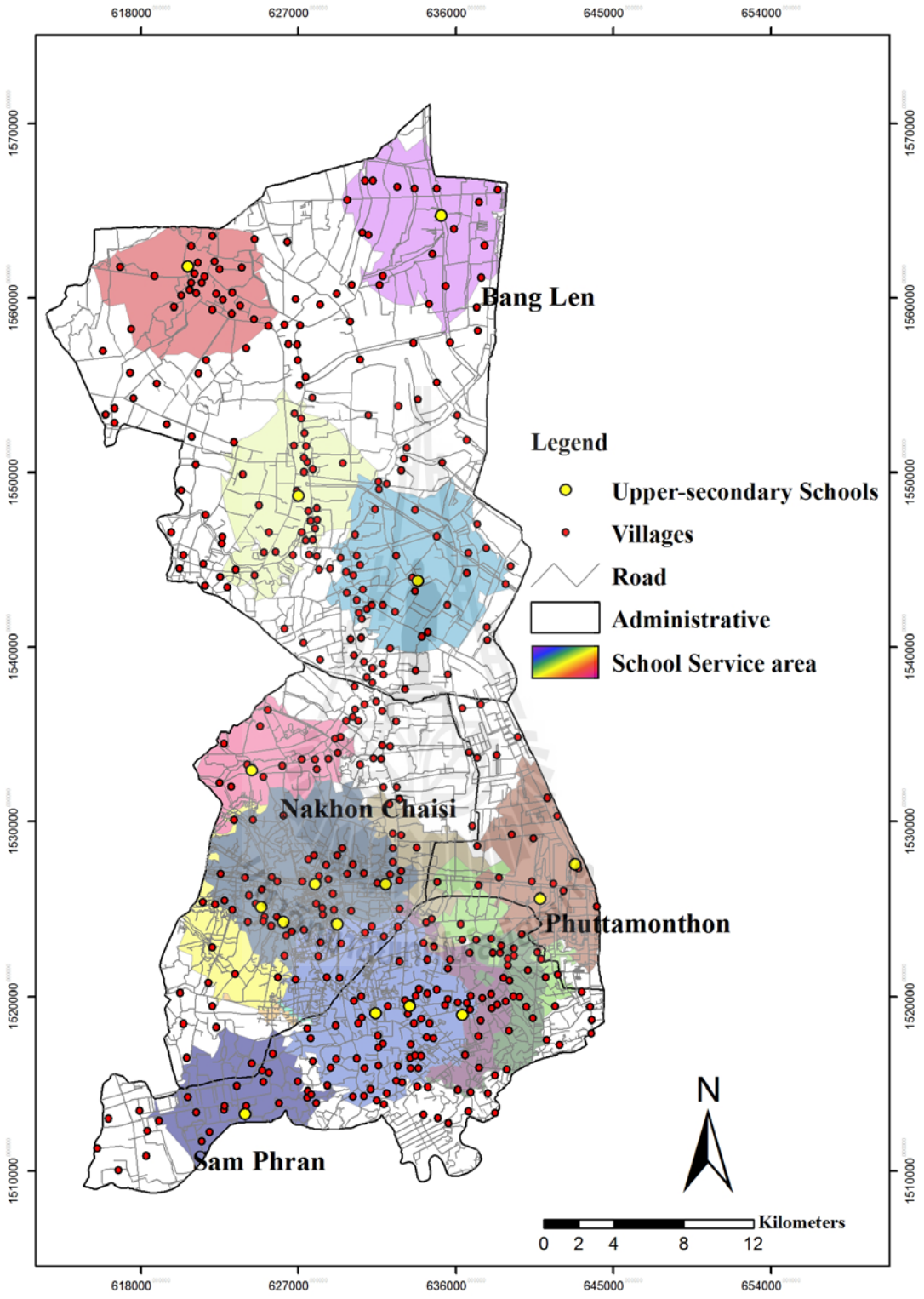


Figure 4.8b Map of the school service areas (7 km limit) at US level (present situation).

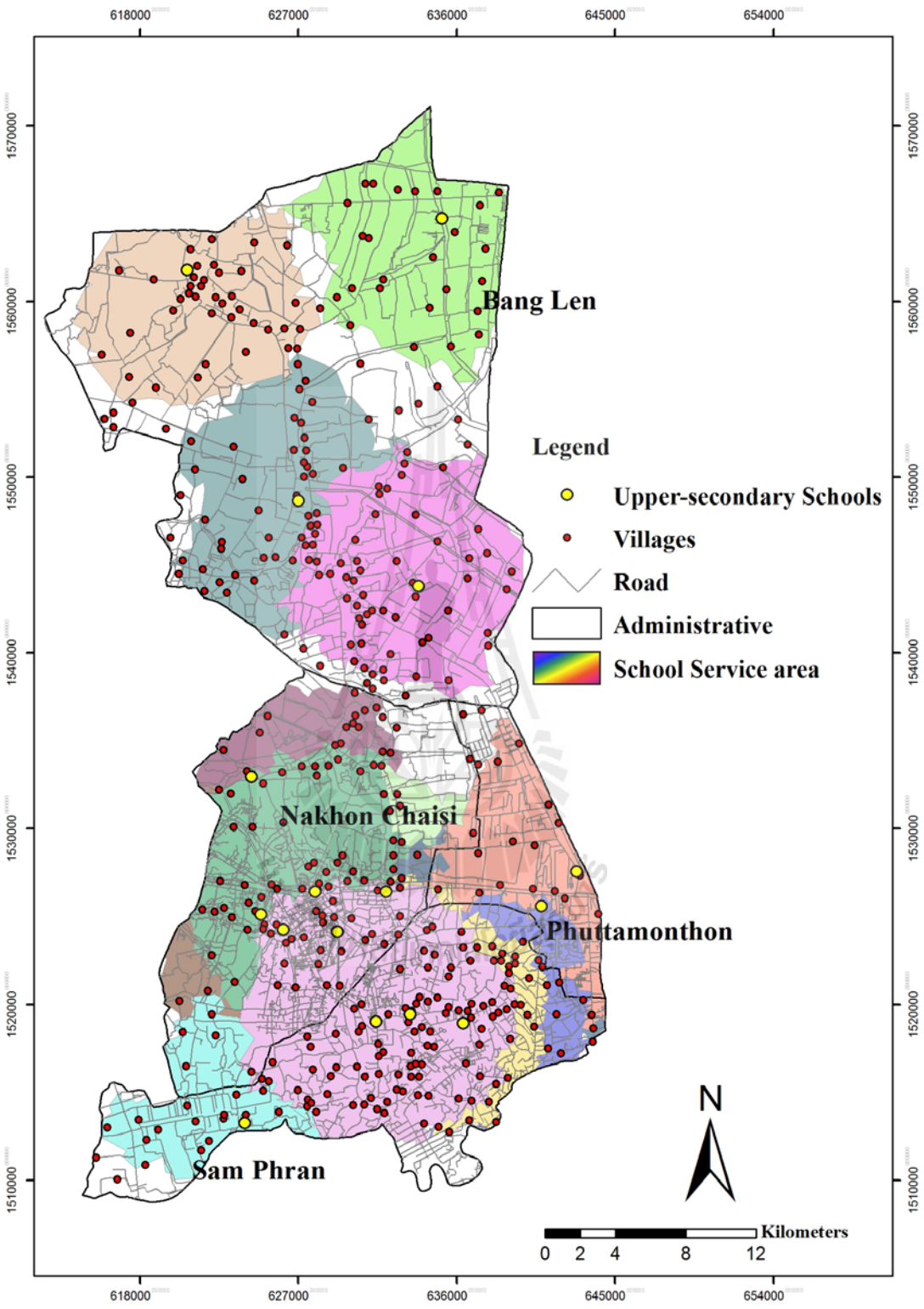


Figure 4.8c Map of the school service areas (10 km limit) at US level (present situation).

It is interesting to find at the distance limit of 3 km (for P and LS levels) and 5 km (for US level) that are preferred by state's policy, the no-service villages become 11.06%, 46.73%, and 53.95%, while the overlapped villages become 49.43%, 10.84%, and 17.38%, respectively. These numbers indicate that present positions of the existing primary schools are relatively sufficient to provide education for the whole study area at 3km-limit criteria (with about 90% coverage), but the overlapped villages of 49.43% (at this limit) implies that number of the existing schools is too high resulted in the relatively crowded school distribution. On the contrary, at distance limits of 3 km (for LS level) and 5 km (for US level), numbers of no-service villages are still relatively high (at 46.73% and 53.95%, respectively) but numbers for those with overlapping services are rather low (at 10.84%, and 17.38%, respectively). This means the current positions of the concerned LS and US schools are considerably well located but their numbers are still not sufficient to serve most villages existing in the area (at the given distance limits).

The possible solutions for this situation are the increases in number of LS and US schools and/or values of distance limit. For examples, if the distance limits become 5 km (for LS level) and 7 km (for US level), numbers of the observed no-service villages will be reduced to be 15.80% and 30.93%, respectively, while those of the overlapped villages shall become 42.66% and 30.48%, respectively. This option might be more convenient to implement than to build more schools in the area which may need a considerable amount of budget to fulfill. Actually, the distance limits of 5 km (for LS level) and 7 km (for US level) should be reasonably accepted nowadays if we assume that students at these levels can travel to school by taking some kinds of the motor vehicles mentioned earlier.

In addition, it is obvious from Figures 4.6a-4.6e, 4.7a-4.7c, and 4.8a-4.8c that, over the upper half of the area (Bang Len District), numbers of the existing school (at each level) are significantly lower than those of the lower half. This makes it less prone to occurrences of overlapped but the prospect of having high no-service area is rather imminent, especially at the LS and US levels (Table 4.4). However, high overlapped area of the P level in Bang Len (41.11%) indicates that school locations are still not distributed well (mostly along main streets.)

Table 4.4 School efficiency in term of the service area at district level (present situation).

BLN	Limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (49)	3	24	13.33	82	45.56	74	41.11	-	-
LS (12)	3	106	58.89	73	40.56	1	0.56	-	-
US (4)	5	132	73.33	48	26.67	-	-	-	-
NCS	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (34)	3	8	7.41	25	23.15	73	67.59	2	1.85
LS (11)	3	33	30.56	50	46.30	25	23.15	-	-
US (6)	5	34	31.48	28	25.93	46	42.59	-	-
PMT	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (8)	3	6	33.33	9	50.00	3	16.67	-	-
LS (5)	3	10	55.56	6	33.33	2	11.11	-	-
US (2)	5	6	33.33	7	38.89	5	27.78	-	-
SPR	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (36)	3	17	12.41	60	43.80	60	43.80	-	-
LS (11)	3	58	42.34	59	43.07	20	14.60	-	-
US (4)	5	67	48.91	44	32.12	26	18.98	-	-

Note: VIL = Number of villages, % ≡ Percent of total villages at each district.

4.2.2 Consideration in term of the service loading

The service loadings (SL) for all schools were computed based on the definition given in Eq. 3.1 and the gain results were separated into 5 classes as stated in Table 3.2. From Table 4.3 (and Figure 4.5), it was found that general trend of the SL values (at each level) depends critically on distance limits where higher one leads to lower number of SL. For examples, at P level, numbers of schools at Low-SL level rise from 14 schools at 2 km limit to 43 schools (3 km), 79 schools (4 km), and 101 schools (5 km), respectively. And at the limits of 3 km (for P/LS levels) and 5 km (for US level) preferred by the state's policy, numbers of schools with low SL are 43 (33.86%), 13 (33.33%), and 2 (12.50%), respectively, where numbers of schools with very high SL values become 16 schools (12.60%), 10 schools (25.64%), and 5 schools (31.25%). Detailed analysis at district level is given in Table 4.5 for distance limits of 3 km (P/LS levels) and 5 km (US level). In general, the Bang Len yielded best results in term of low-SL schools while Nakhon Chai Si yielded worst at all school levels.

These results indicate that at these preferred distance limits, numbers of schools with low SL are still relatively high, especially at P level. This might be due to the large number of schools at P-level residing in the area (127 schools) that leads to the potential low rate of attending to the comparatively less attractive ones situating in the area. Relatively high numbers of the LS and US-level schools with very high SL values reflect capability of these schools to attract potential students living far beyond the prescribed distance limits. This situation might affect effectiveness of the other schools (at same level) that are less competitive in recruiting their new students and providing proper services to the potential students residing within their service areas.

Table 4.5 School efficiency in term of the service loading (present situation).

SL level	P level					LS level			US level		
	1 km	**2 km**	**3 km**	**4 km**	**5 km**	**3 km**	**5 km**	**7 km**	**5 km**	**7 km**	**10 km**
L (critical)	-	14	43	79	101	13	23	23	2	3	6
ML (normal)	12	28	40	30	17	8	10	10	2	3	4
MH (normal)	4	17	17	7	7	7	4	4	4	4	4
H (concerned)	9	13	6	4	1	1	2	2	3	5	2
VH (critical)	36	34	16	7	1	10	-	-	5	1	-
Other	66	21	5	-	-	-	-	-	-	-	-
Total schools	127	127	127	127	127	39	39	39	16	16	16

Note: 1. L ≡ Low, ML ≡ Medium low, MH ≡ Medium high, H ≡ High, VH ≡ Very high.

2. Other ≡ Cases with POT = 0.

Table 4.6 Average SL values for different categories of school scales (present situation).

Schoo lscale	P level				LS level			US level		
	1 km	**2 km**	**3 km**	**5 km**	**3 km**	**5 km**	**7 km**	**5 km**	**7 km**	**10 km**
S	221.1	152.2	73.8	24.2	40.8	20.1	8.2	19.0	9.9	5.84
M	517.3	255.1	112.8	39.6	120.4	53.8	29.7	32.6	19.5	10.25
L	856.9	209.2	145.6	60.3	484.3	91.4	62.0	75.0	57.1	28.51
VL	956.1	343.9	167.1	85.0	281.3	96.9	48.0	-	-	-

Note: 1. Cases with POT ≡ 0 were not included in the analysis.

2. School scale: S ≡ Small (1-120 students), M ≡ Medium (121-600 students),

L ≡ Large (601-1500 students), VL ≡ Very large (>1500 students).

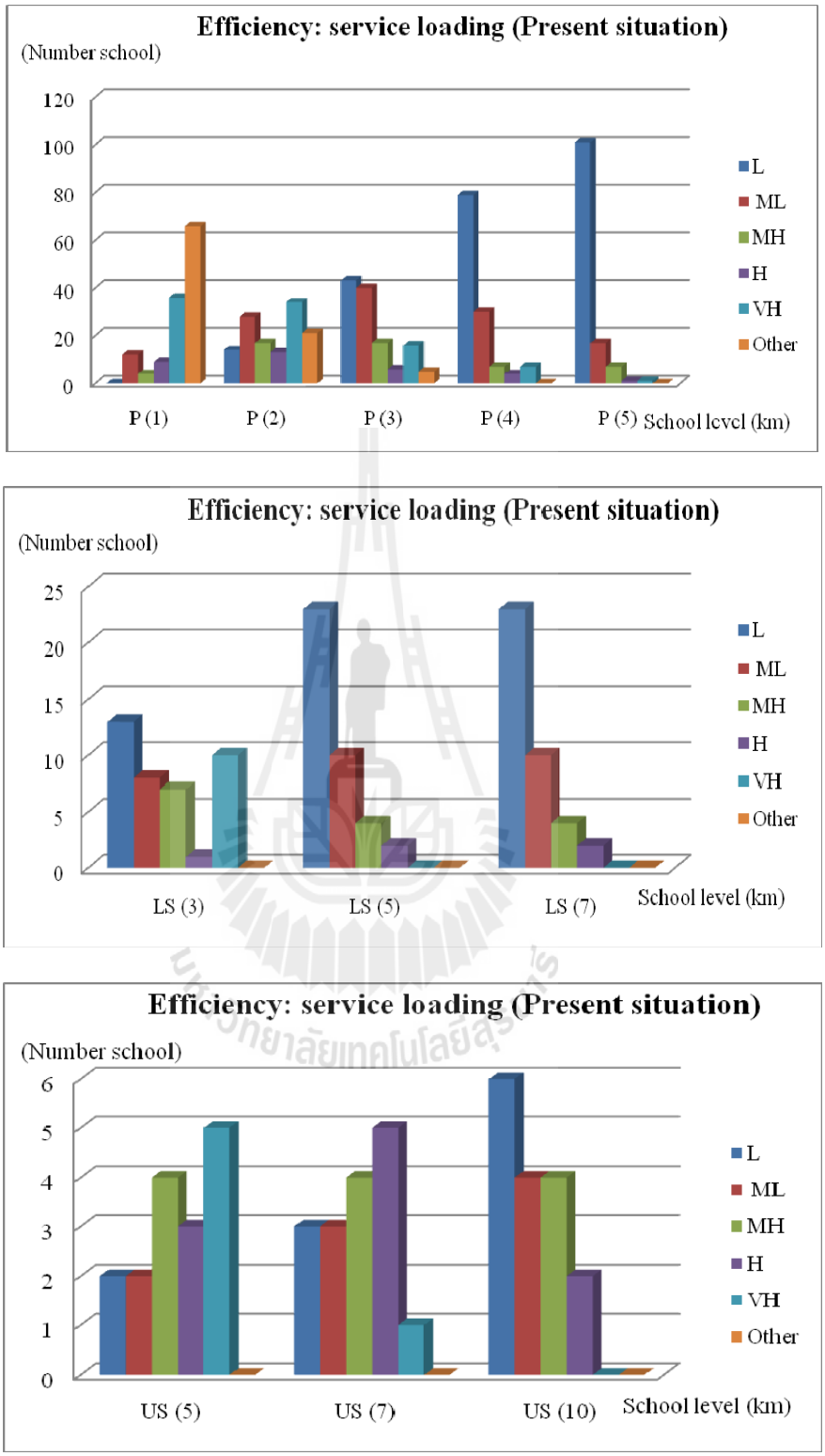


Figure 4.9 School efficiency in term of service loading from Table 4.5 (present situation).

Table 4.7 School efficiency in term of service loading at district level (present situation).

BLN	Limits (km)	L		ML		MH		H/VH		Other	
		SCH	%	SCH	%	SCH	%	SCH	%	SCH	%
P (49)	3	8	16.33	19	38.78	8	16.33	10	20.41	4	8.16
LS (12)	3	3	25.00	1	8.33	4	33.33	4	33.33	-	-
US (4)	5	-	-	-	-	2	50.00	2	50.00	-	-
NCS	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (34)	3	17	50.00	13	38.24	2	5.88	1	2.94	1	2.94
LS (11)	3	5	45.45	3	27.27	2	18.18	1	9.09	-	-
US (6)	5	3	50.00	3	50.00	-	-	-	-	-	-
PMT	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (8)	3	2	25.00	1	12.50	1	12.50	4	50.00	-	-
LS (5)	3	2	40.00	-	-	-	-	3	60.00	-	-
US (2)	5	-	-	-	-	1	50.00	1	50.00	-	-
SPR	**Limits (km))**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (36)	3	16	44.44	7	19.44	6	16.67	7	19.44	-	-
LS (11)	3	3	27.27	4	36.36	1	9.09	3	27.27	-	-
US (4)	5	1	25.00	1	25.00	2	50.00	-	-	-	-

Note: 1. SCH ≡ number of schools, % ≡ percent of total schools at each district (at a specific level).

2. Other ≡ Cases with POT = 0.

Table 4.6 demonstrates that average SL value (at each school scale) significantly decreases as the given distance limit increases. For example, average SL values at P-level for distance limits of 1, 2, and 3 km are 221.1%, 152.2%, and 73.8%, respectively. This means the servicing capability of the studied schools (in term of SL value) shall be dramatically reduced if their service distances are extended. It is interesting to find that the existing small schools at P level under consideration have high average SL of 221.1% at 1km limit. However, this does not mean most P schools did well in term of SL values as there were still 39 small schools (with POT = 0) being omitted (30.71% of total school number).

It should be noted that as the derivation of SL value for each relevant school was performed independently based on the known values of its actual and potential students residing within the specified service area, this method might lead to an under-estimation of the SL values for schools whose service areas being overlapped. This is because under this situation these schools have to compete with each other to attract students living over the overlapping area to attend their school and have to regard all potential students found at that area to be their target group which is not true in practice. These two reasons can result in the lower SL values for these schools when compare to schools that do not have to compete much with other neighboring schools (at same school level), or do not have much of the overlapped area. As a consequence, the interpretation of the found SL values in term of school's efficiency must be performed with particularly cautious. In addition, as the strict school's service area policy is still not implemented in Thailand and students can attend any schools available to them regardless of the travel distance, this can cause substantial difficulty in the interpretation of a school's SL value properly.

Table 4.8 Comparison of school efficiency in term of the average travel distance.

Distance (km)	P level			LS level			US level		
	PR-1 (127)	**PR-2 (127)**	**CLT (50)**	**PR-1 (39)**	**PR-2 (39)**	**CLT (50)**	**PR-1 (16)**	**PR-2 (16)**	**CLT (18)**
Maximum	5.02	29.42	7.78	8.33	10.29	7.58	13.16	39.92	12.83
Average	1.62	2.63	2.46	2.66	4.84	2.40	4.80	10.56	4.19

Note: 1. PR-1 ≡ Present situation (students attend the closest existing school only)
PR-2 ≡ Present situation (students attend closest schools recommended by authorities only).
2. CLT ≡ Idealized scenario (students attend closest schools recommended by idealized analysis).

4.2.3 Consideration in term of the travel distance to school

In this case, average travel distances to school (along road network) per potential student are considered under some given criteria. The important criteria are that a student can attend only one school (at each level) closest to their residences (assumed to be at the corresponding village location) and there is no limit set on the travel distance (similar to those required in the p-median and gravity p-median models). In addition, average travel distance of the students to specific schools that are presently designated to them by the local authorities is also evaluated at all 3 levels. However, only at P level that the one-to-one matching between designated school and village is arranged, but at LS and US levels, 1-3 schools are normally attached to a single village. Therefore, in finding average travel distance at the LS and US levels (case PR-2), a student is assumed to attend the closest school under the state's recommendation only. There are two distance-based parameters being considered (in km unit): the maximum travel distance and the average distance (per student), under three scenarios as described in Table 4.8.

Results reported in Table 4.8 indicate that average travel distances of the potential P-level students under PR-1 and PR-2 situations are approximately 1.62 and 2.63 km, respectively but these values increase to 2.66 and 4.84 km for the LS-level students and 4.80 and 10.56 km for the US-level students. This means students have to travel to school at longer distance if level of the school increases (from P to LS and then US). The found value of 1.62 km at P-level (of PR-1 scenario) is reasonably acceptable for the walking and cycling modes of traveling to school, and values of 2.66 and 4.80 km at LS and US levels (of PR-1 scenario) are rather practical for the cycling and motor-vehicles-based modes of traveling for most students at these levels.

However, it is interesting to find that average travel distances at all school levels of the PR-2 scenario (students attend closest schools recommended by authorities only) are noticeably higher than those of the PR-1 scenario (students attend the closest existing school only) (about 60% at P level, 90% at LS level, and 120% for the US level). These differences are more obvious in term of the gained maximum travel distance. For examples, the maximum distance values at P and US levels of the PR-1 case are only 5.02 and 13.16 km, compared to those of the PR-2 case, which are 29.42 and 39.92 km, respectively. Based on these obtained results, it can be primarily concluded that present school zoning system authorized by the responsible state's agency is still rather ineffective in reducing average travel distance of the students at all educational levels when compared to the simple strategy of assigning the students to their existing closest schools (along road network) only.

4.3 Application of the Idealized Method

Main objective of this section is to generate new school maps for the study area (at all levels) based on the preferred numbers of schools seen in Table 3.3 and the criteria described in Section 3.2.3. These new school maps were created to reduce or abolish the no-service or overlapped service areas and the existing small-scale/low SL schools seen in the area. However, no-service areas should still be seen in some remote regions (from main roads or district centers), especially in Bang Len District. And the overlapping areas might still occur in some parts of the area where the population density is relatively high, or several existing medium/large schools locate close to each other (especially within the lower half of the area) as described in Table 4.10

4.3.1 Formulation of the relevant school maps

Tables 4.9a, 4.9b, and 4.9c are presented details of the preferred school locations (at each level) from the idealized method in according with the school numbers seen in Table 3.3 (district level). Then, the associated school location maps for all selected sites (and their corresponding service areas) at each school level were constructed as illustrated in Figures 4.10a-4.10e (P level), 4.11a-4.11c (LS level), and 4.12a-4.12c (US level).

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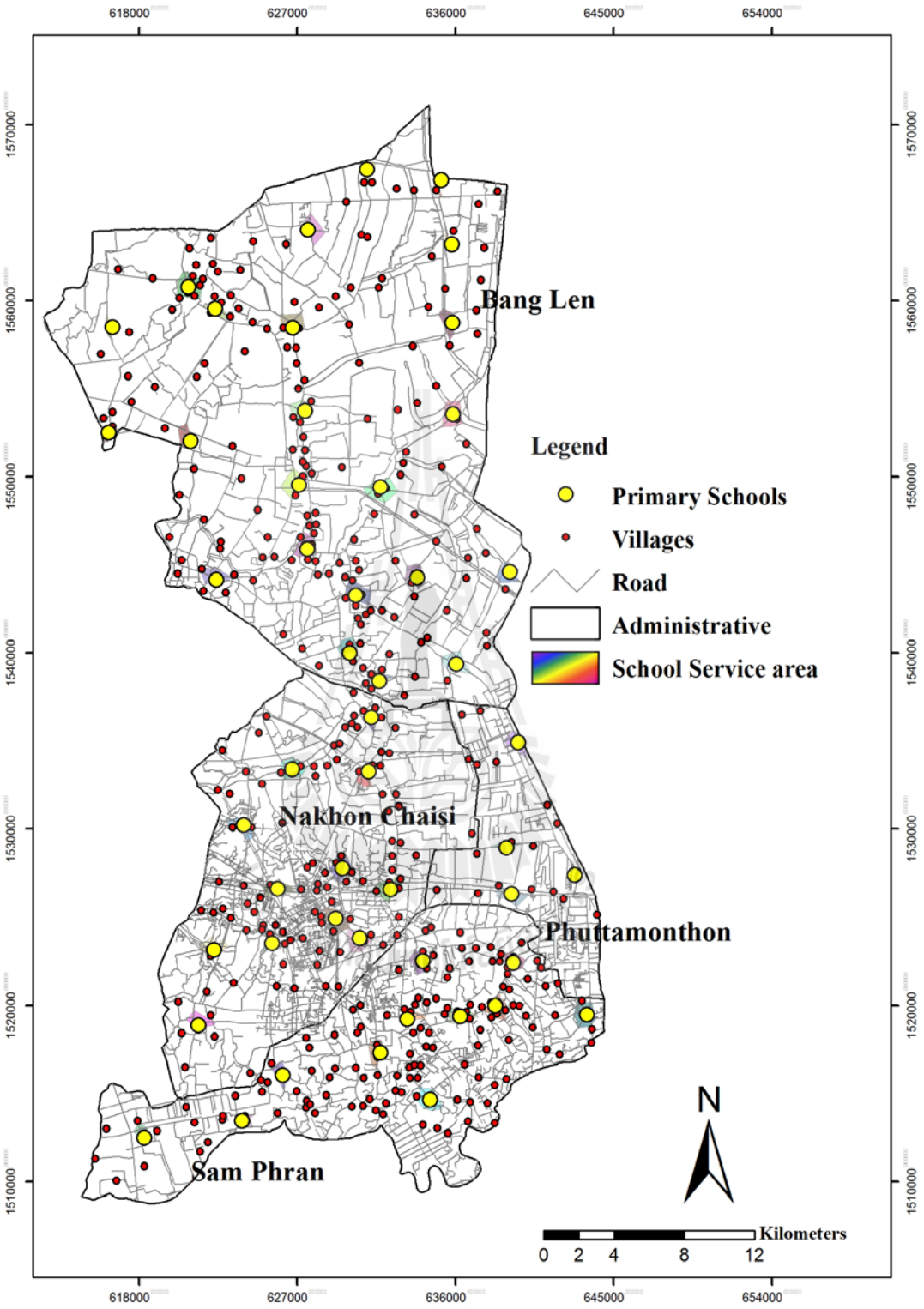


Figure 4.10a Map of the school service areas (1 km limit) at P level (idealized).

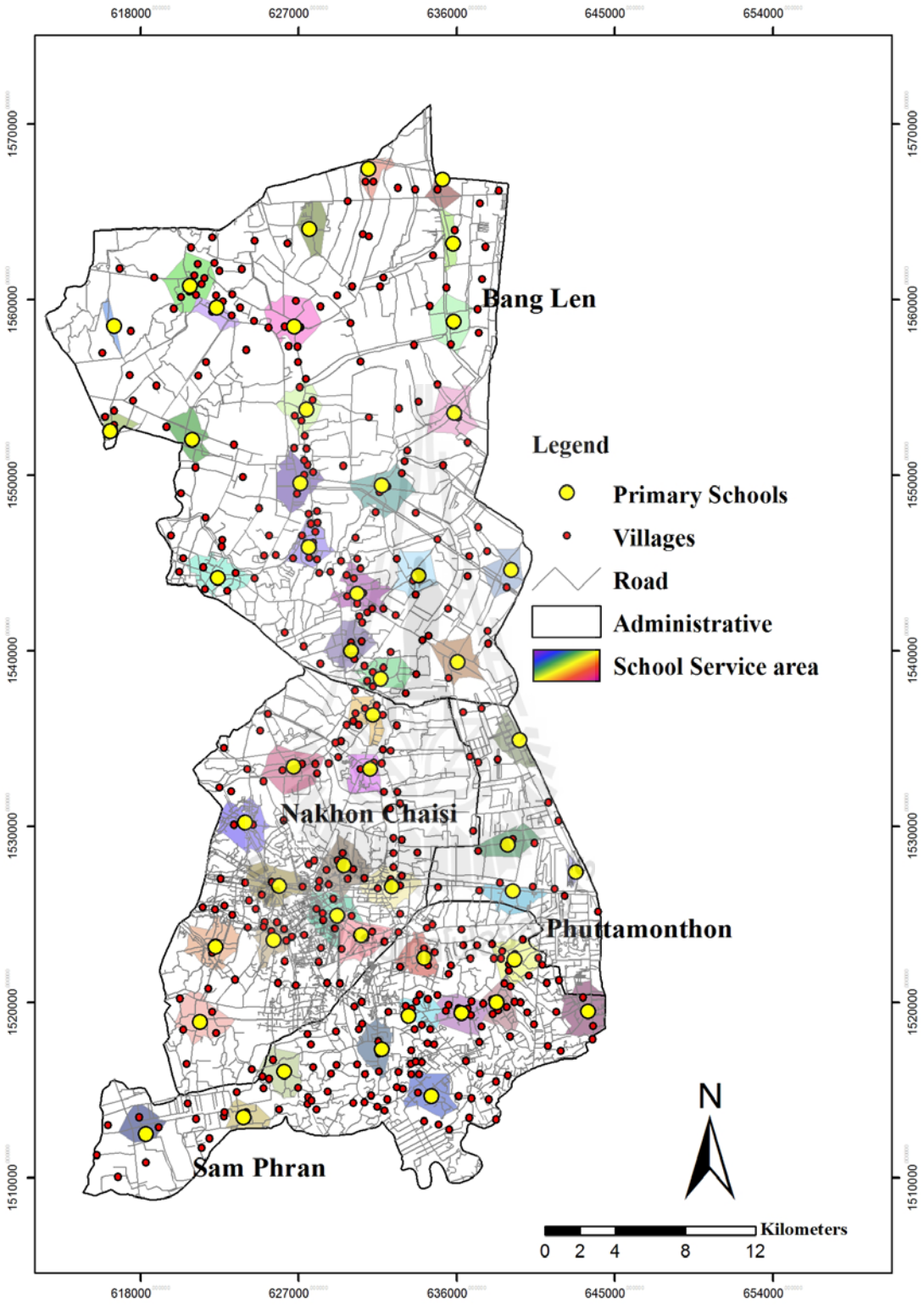


Figure 4.10b Map of the school service areas (2 km limit) at P level (idealized).

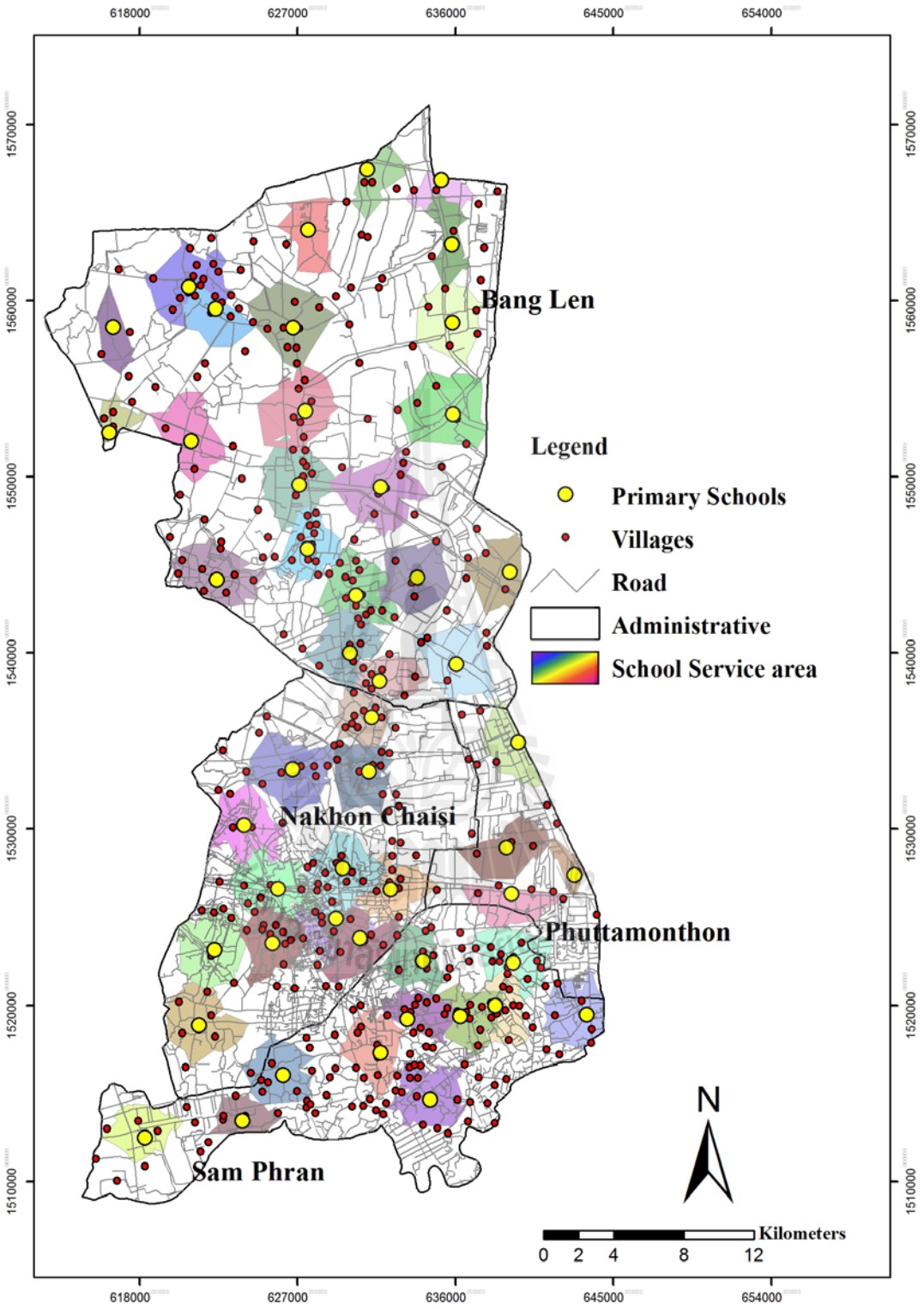


Figure 4.10c Map of the school service areas (3 km limit) at P level (idealized).

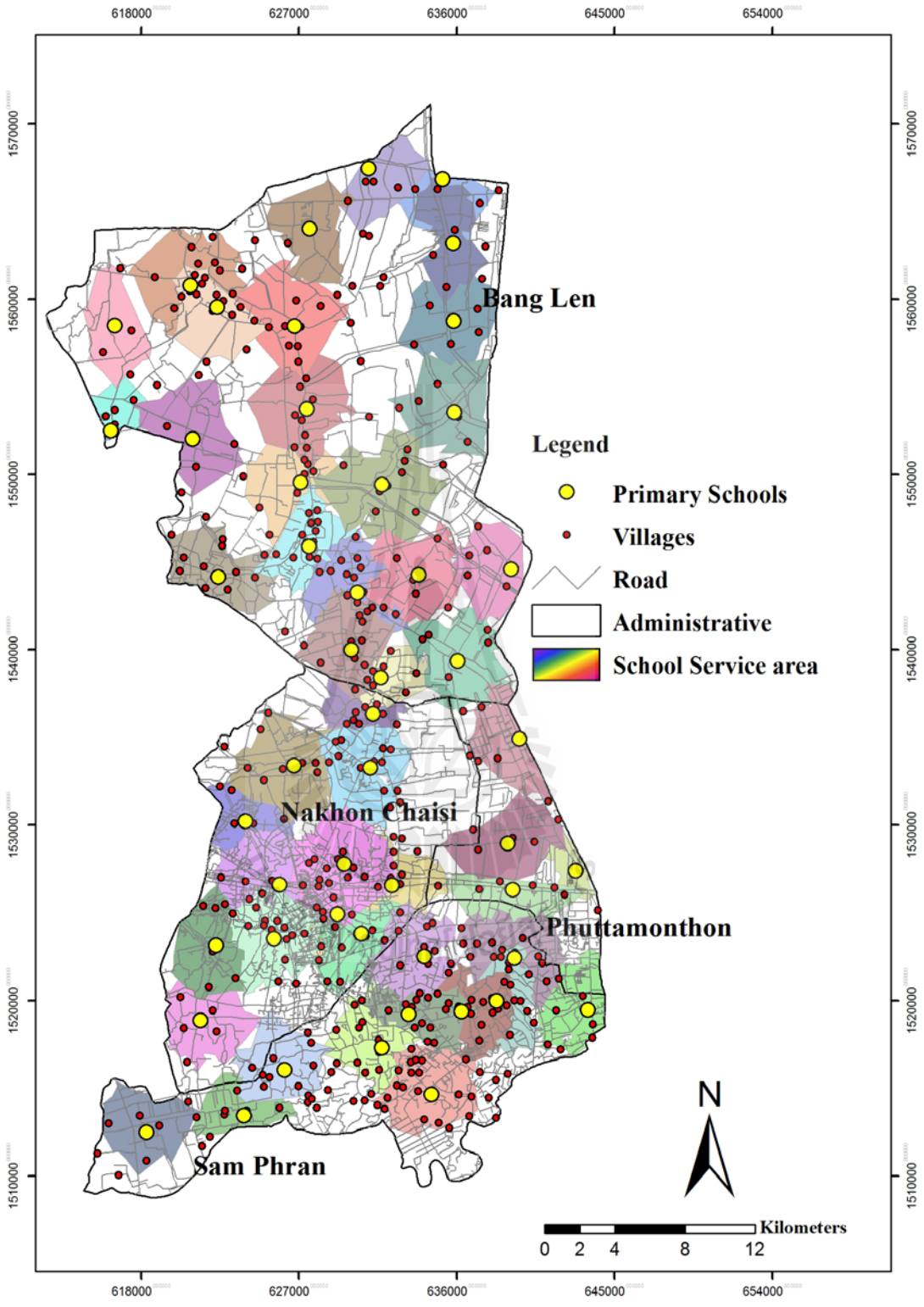


Figure 4.10d Map of the school service areas (4 km limit) at P level (idealized).

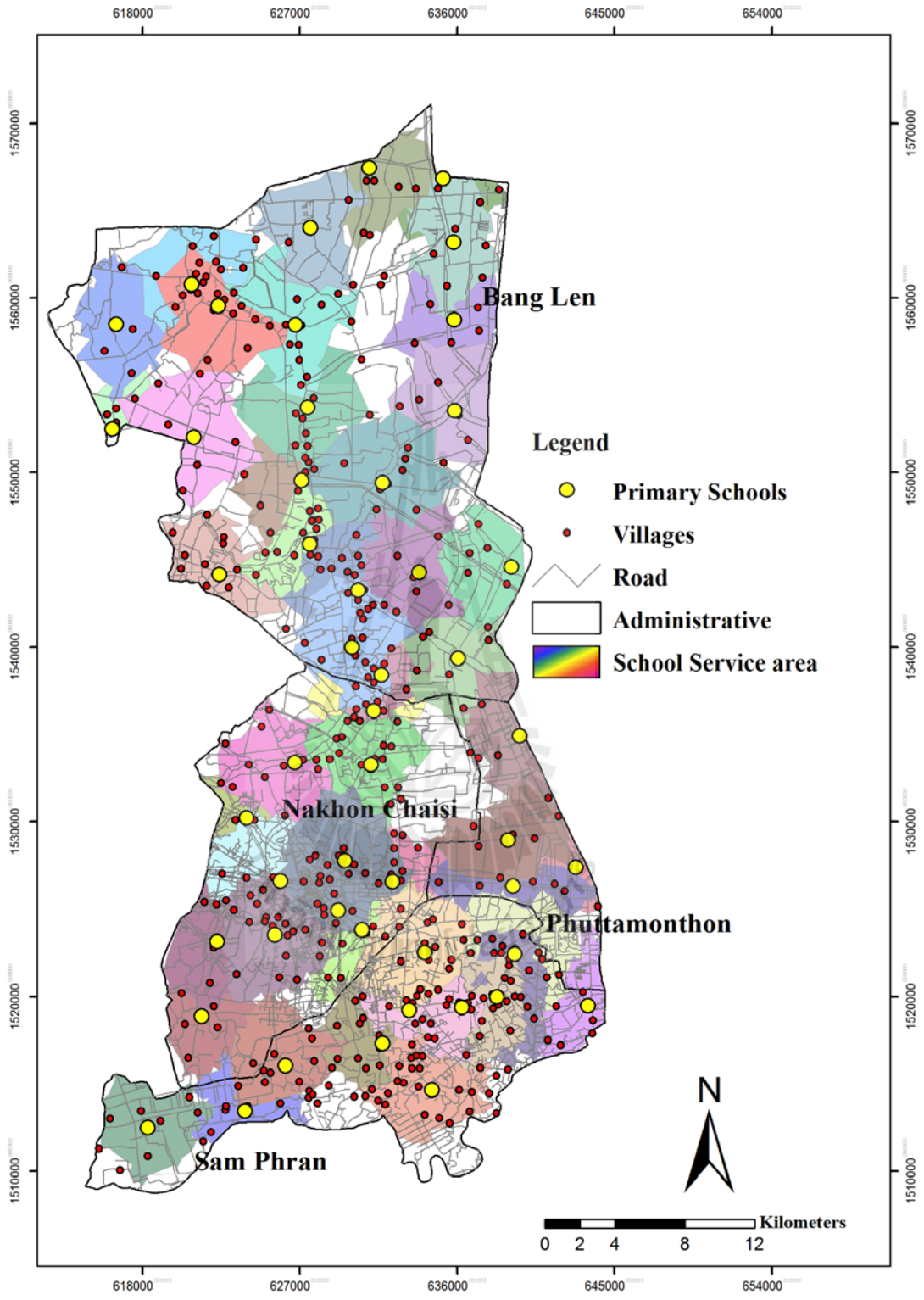


Figure 4.10e Map of the school service areas (5 km limit) at P level (idealized).

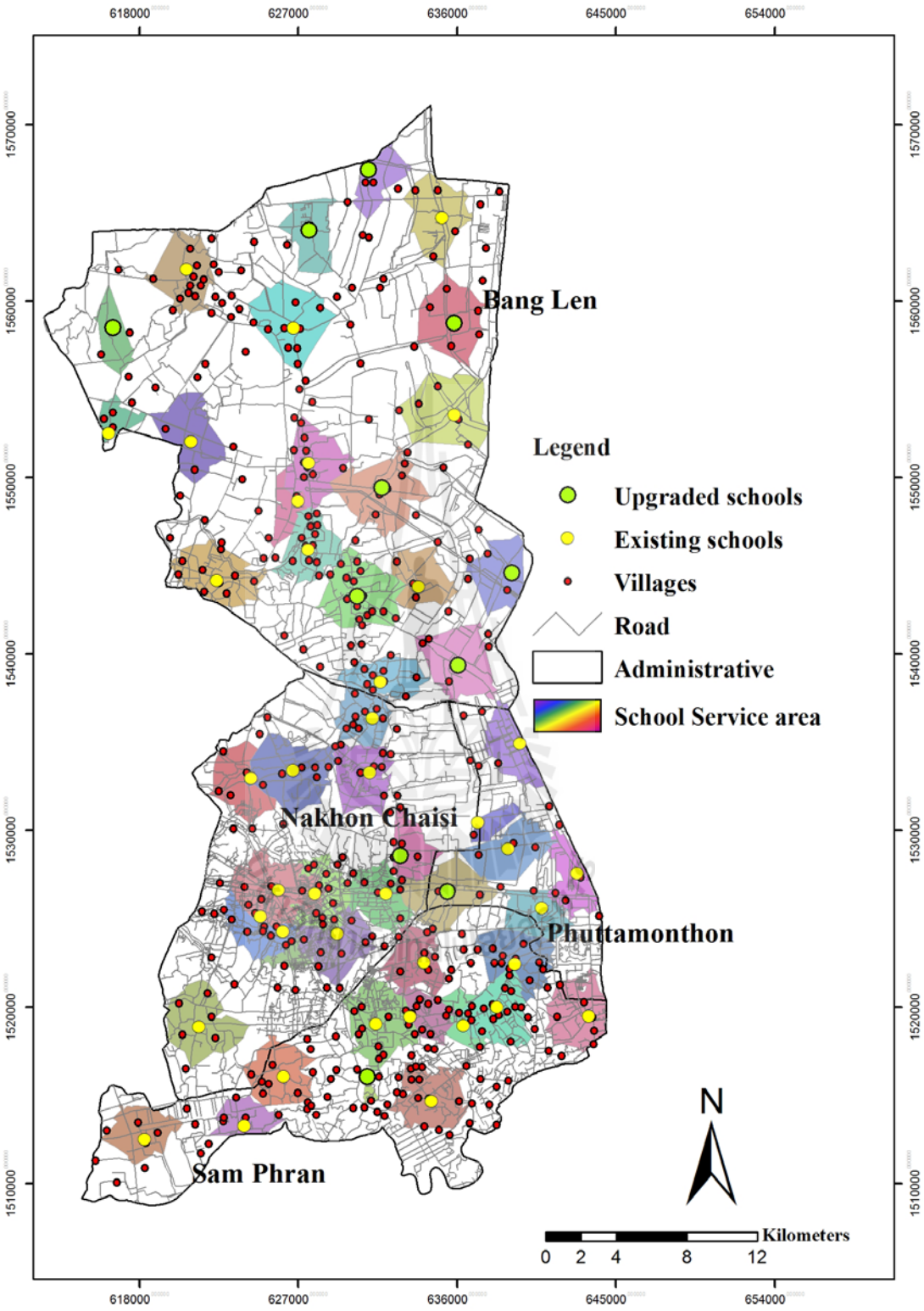


Figure 4.11a Map of the school service areas (3 km limit) at LS level (idealized).

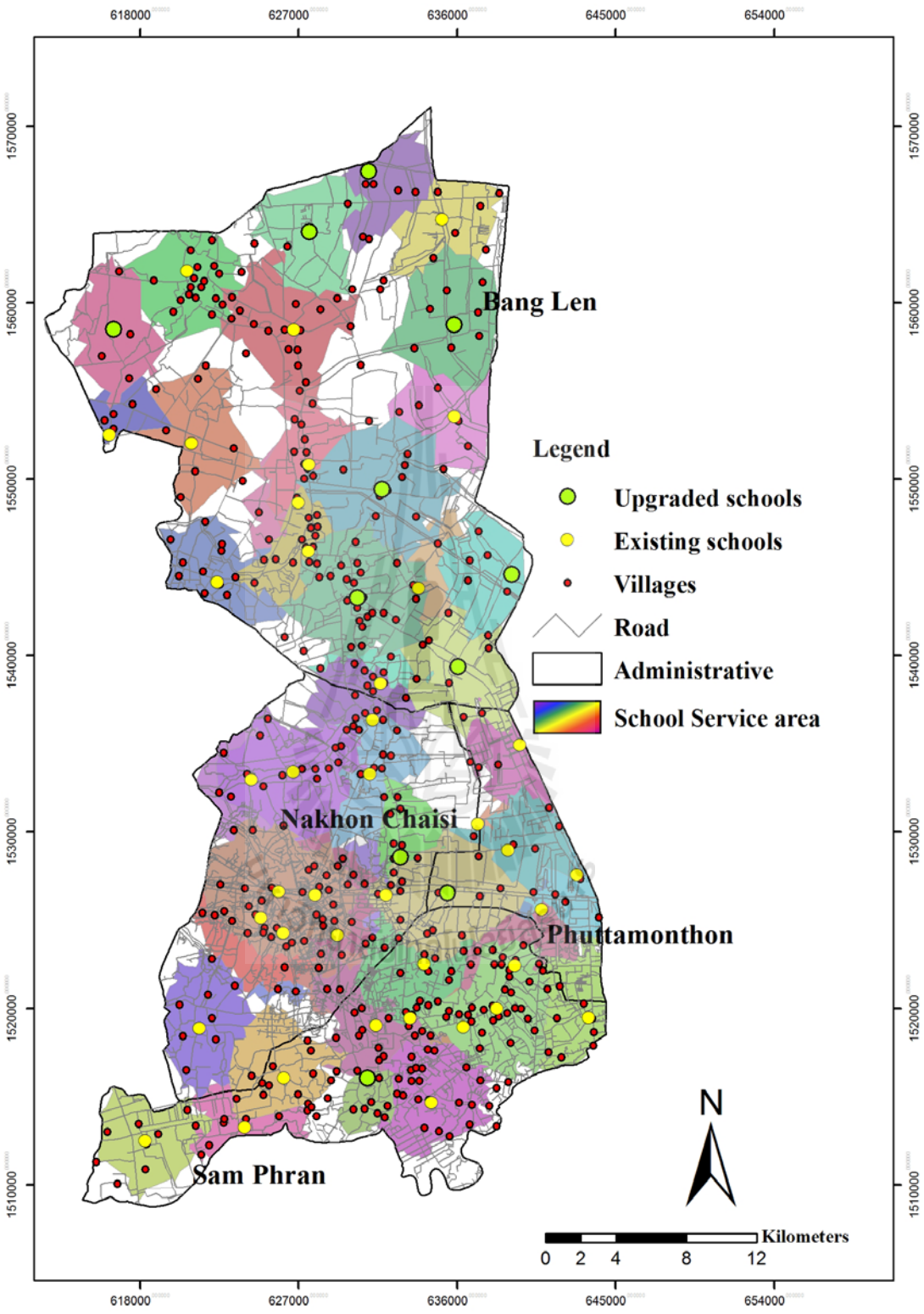


Figure 4.11b Map of the school service areas (5 km limit) at LS level (idealized).

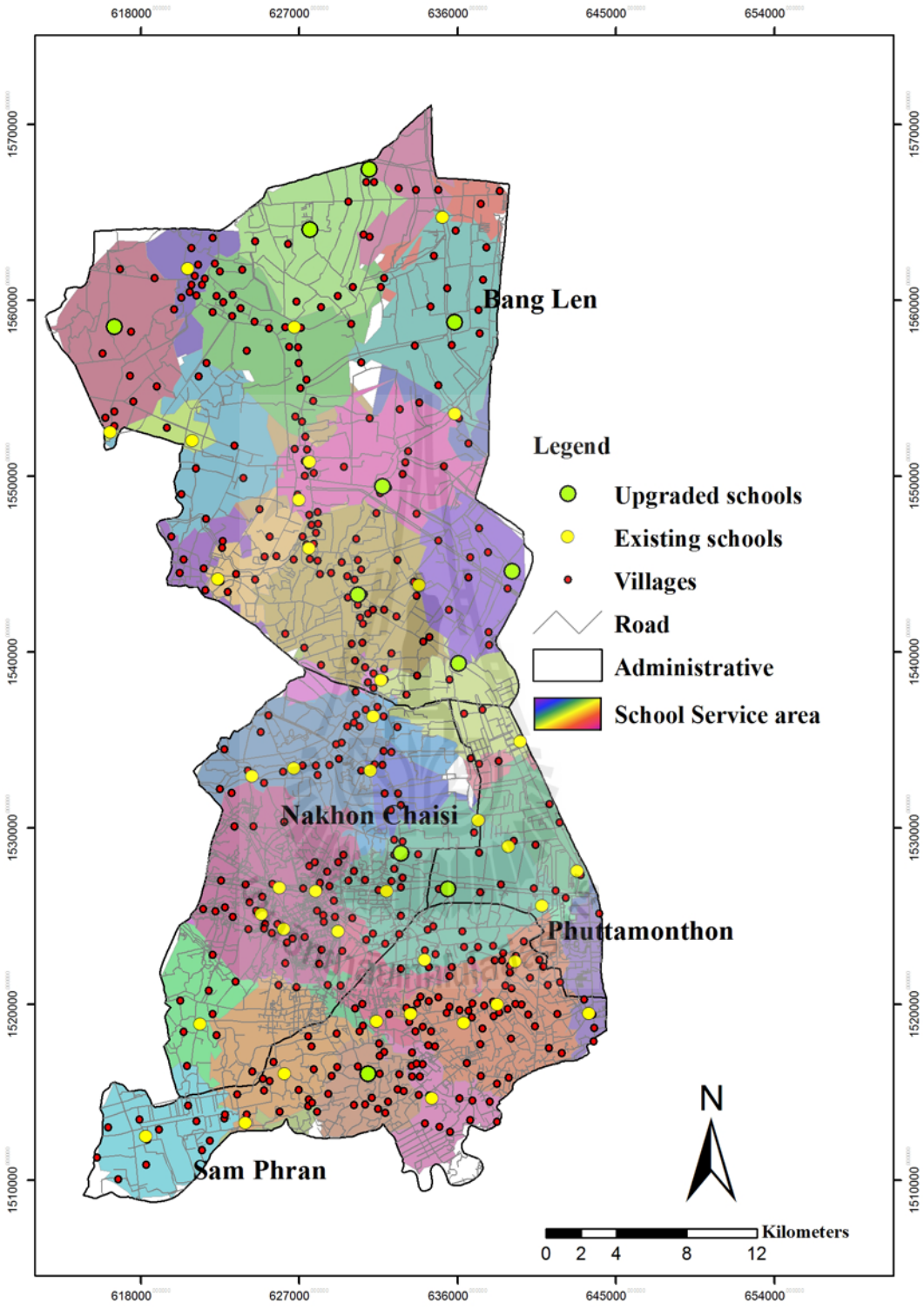


Figure 4.11c Map of the school service areas (7 km limit) at LS level (idealized).

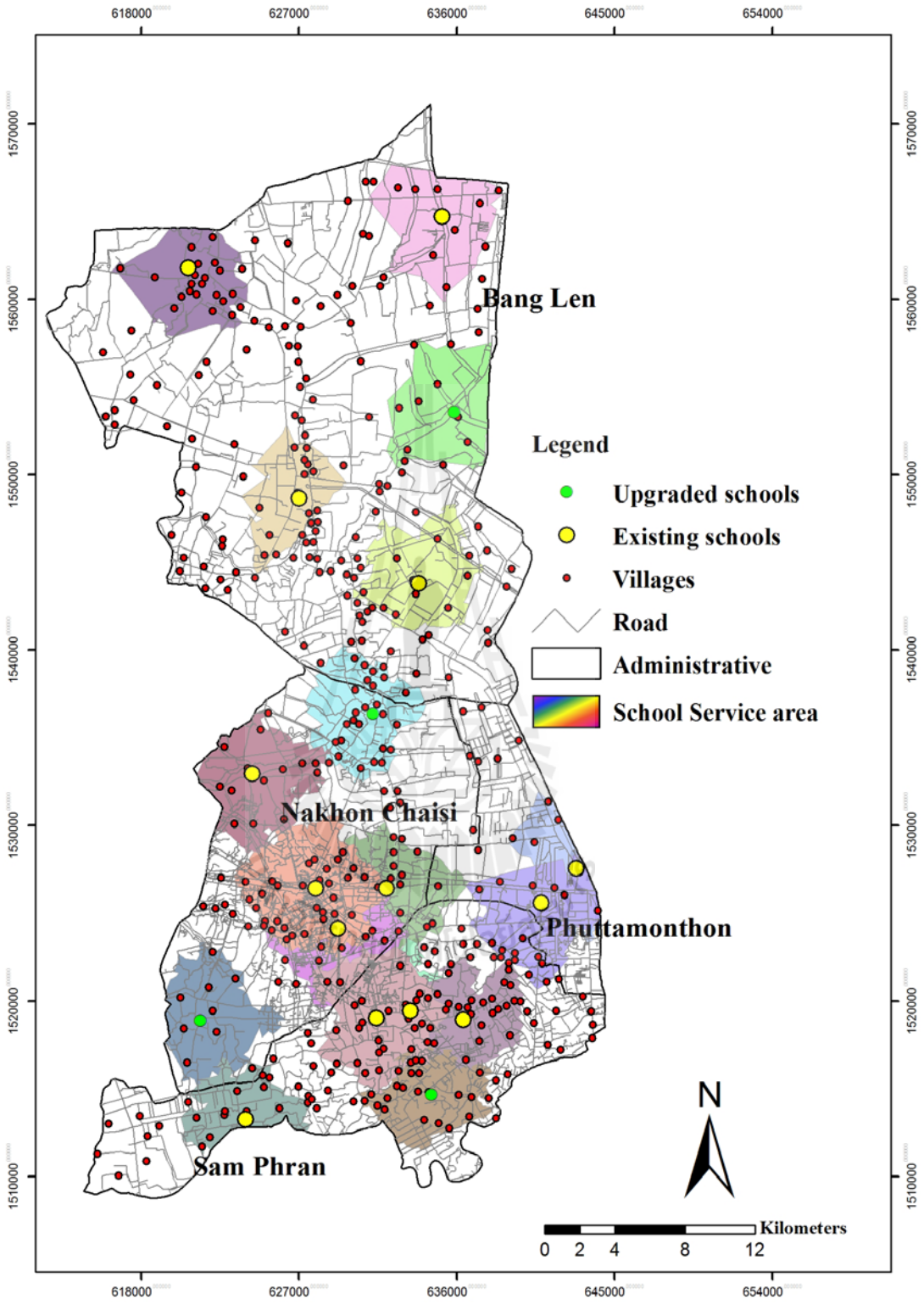


Figure 4.12a Map of the school service areas (5 km limit) at US level (idealized).

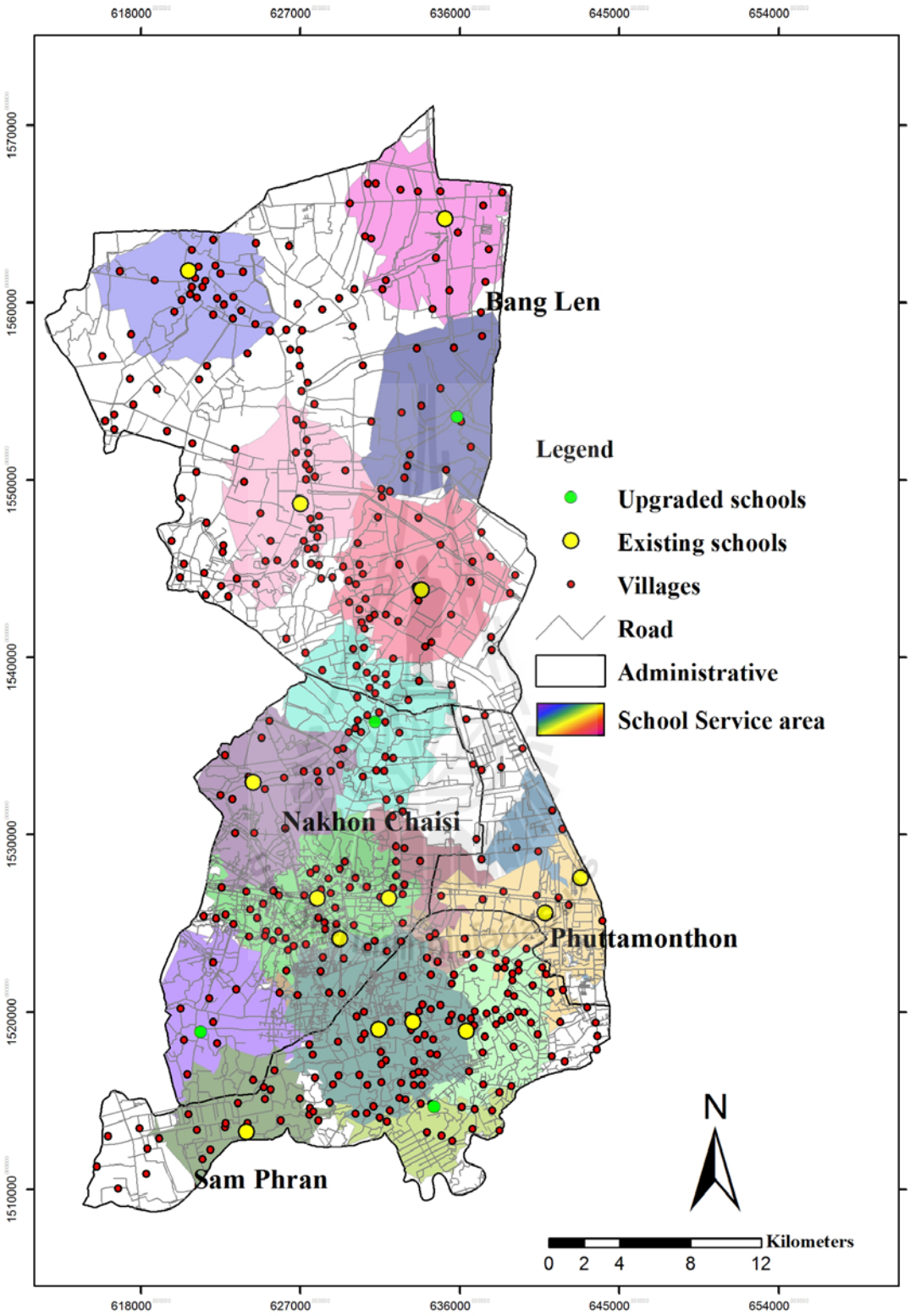


Figure 4.12b Map of the school service areas (7 km limit) at US level (idealized).

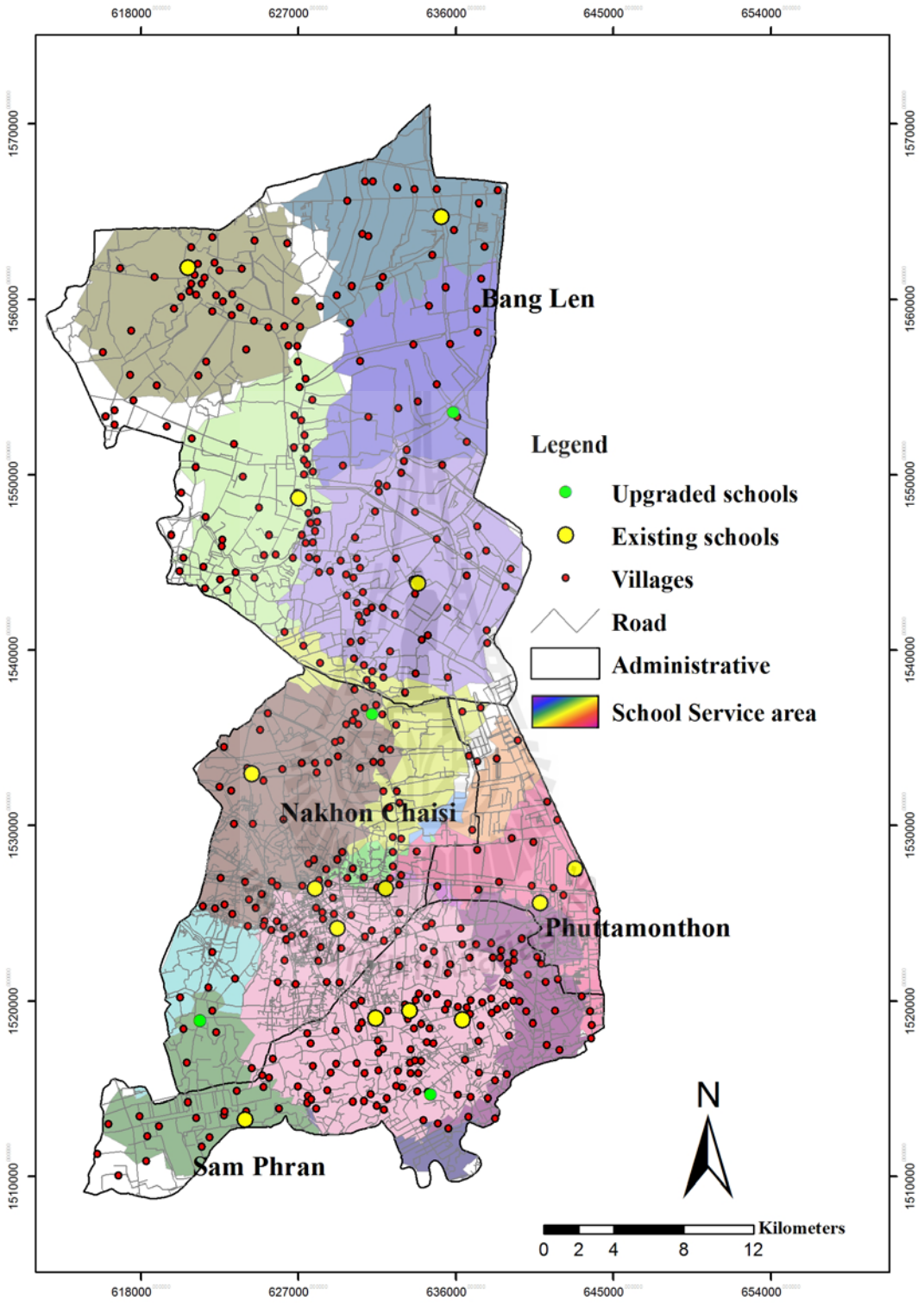


Figure 4.12c Map of the school service areas (10 km limit) at US level (idealized).

Table 4.9a Information of the 50 selected sites at P level (idealized).

Bang Len (23)					**Bang Len (23)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB3	P	L	บ้านบางเลน	TB1	SB30	P	M	วัดบัวหวั่น	TB7
SB6	P	S	บ้านลาดหลวง	TB2	SB34	P/LS	M	วัดลานคา	TB8
SB7	P	S	บ้านหนองมะม่วง	TB2	SB36	P	M	วัดศิลามูล	TB9
SB11	P	L	วัดบางหลวง	TB2	SB39	P	M	วัดเวฬุวนาราม	TB11
SB16	P	M	วัดรางกำหยาด	TB3	SB40	P	M	วัดลำพญา	TB11
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB44	P	M	วัดสว่างอารมณ์	TB12
SB20	P/LS	M	ตลาดเกาะแรต	TB4	SB45	P	M	วัดนราภิรมย์	TB12
SB21	P/LS	M	วัดบางปลา	TB4	SB47	P	M	วัดนิลเพชร	TB13
SB23	P	M	วัดสุขวัฒนาราม	TB5	SB49	P/LS	M	วัดไผ่หูช้าง	TB14
SB24	P/LS	M	ไทยรัฐวิทยา 4	TB5	SB52	P	M	วัดเกษตราราม	TB15
SB26	P	M	วัดบางไผ่นารถ	TB6	SB53	P/LS	M	วัดโพธิ์	TB15
SB29	P	M	ตลาดเจริญสุข	TB7	-	-	-	-	-
Nakhon Chai Si (12)					**Nakhon Chai Si (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**		
SN2	P/LS	M	วัดบางพระ	TN2	SN14	P	M	วัดท้องไทร	TN10
SN5	P	M	วัดบ่อตะกั่ว	TN5	SN20	P	L	วัดกลางบางแก้ว	TN12
SN8	P/LS	L	วัดห้วยพลู	TN7	SN22	P	L	วัดงิ้วราย	TN13
SN9	P/LS	L	วัดโคกพระเจดีย์	TN8	SN25	P	L	วัดไทร	TN15
SN10	P	M	วัดประชานาถ	TN9	SN30	P	L	วัดกกตาล	TN19
SN12	P/LS	L	วัดศรีมหาโพธิ	TN9	SN33	P/LS	M	วัดศรียะทอง	TN20
Phutthamonthon (4)					**Phutthamonthon (4)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	M	วัดมะเกลือ	TP1	SP6	P	M	วัดสุวรรณาราม	TP3
SP5	P/LS	L	บ้านคลองโยง	TP2	SP8	P	VL	พระตำหนักฯ	TP3
Sam Phran (11)					**Sam Phran** (11)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	VL	วัดเทียนดัด	TS1	SS26	P/LS	L	วัดท่าพูด	TS10
SS8	P/LS	VL	วัดดอนหวาย	TS3	SS27	P	VL	วัดไร่ขิง	TS10
SS11	P/LS	L	วัดหอมเกร็ด	TS5	SS30	P	VL	บ้านสามพราน	TS11
SS15	P	M	วัดปรีดาราม	TS6	SS35	P/LS	L	วัดจินดาราม	TS13
SS16	P/LS	M	วัดวังน้ำขาว	TS6	SS39	P	M	วัดสรรเพชญ	TS16
SS22	P/LS	VL	บ้านกระทุ่มล้ม	TS8	-	-	-	-	-

Note: TAM ≡ Tambon, Scale ≡ Resulted school scale in the idealized scenario.

Table 4.9b Data of the 50 selected sites at LS level (idealized).

Bang Len (20)					Bang Len (20)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB4	P/LS	M	บ้านประตูน้ำพระพิมล	TB1	SB30	P	M	วัดบัวหวั่น	SB30
SB5	LS/US	L	บางเลนวิทยา	TB1	SB31	P/US	M	บัวปากท่าวิทยา	SB31
SB6	P	S	บ้านลาดหลวง	TB2	SB34	P/LS	M	วัดลานคา	SB34
SB7	P	S	บ้านหนองมะม่วง	TB2	SB40	P	M	วัดลำพญา	TB11
SB12	LS/US	M	บางหลวงวิทยา	TB2	SB41	LS/US	M	สถาพรวิทยา	SB41
SB16	P	M	วัดรางกำหยาด	TB3	SB44	P	S	วัดสว่างอารมณ์	TB12
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB45	P	M	วัดนราภิรมย์	TB12
SB20	P/LS	S	ตลาดเกาะแรต	TB4	SB49	P/LS	S	วัดไผ่หูช้าง	TB14
SB21	P/LS	S	วัดบางปลา	TB4	SB52	P	M	วัดเกษตราราม	TB15
SB24	P/LS	S	ไทยรัฐวิทยา 4	TB5	SB53	P/LS	M	วัดโพธิ์	TB15
Nakhon Chai Si (12)					**Nakhon Chai Si (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN1	LS/US	M	ปรกแก้ววิทยา	TN1	SN19	P	M	วัดลานตากฟ้า	TN11
SN2	P/LS	M	วัดบางพระ	TN2	SN21	LS/US	M	เพิ่มวิทยา	TN12
SN8	P/LS	S	วัดห้วยพลู	TN7	SN27	LS/US	M	พลอยจาตุรจินดา	TN16
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN33	P/LS	M	วัดศรีษะทอง	TN20
SN12	P/LS	M	วัดศรีมหาโพธิ	TN9	SN34	LS/US	M	จิ้วรายบุญมีรังสฤษดิ์	TN21
SN17	LS/US	M	แหลมบัววิทยา	TN10	SN36	LS/US	L	ภัทรญาณวิทยา	TN22
Phutthamonthon (6)					**Phutthamonthon (6)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP2	P/LS	S	บ้านคลองสว่างอารมณ์	TP1	SP5	P/LS	S	บ้านคลองโยง	TP2
SP3	P/LS	M	วัดมะเกลือ	TP1	SP9	LS/US	L	รัตนโกสินทร์	TP3
SP4	P	-	บ้านคลองมหาสวัสดิ์	TP2	SP10	LS/US	L	กาญจนาภิเษกฯ	TP3
Sam Phran (12)					**Sam Phran (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	M	วัดเทียนดัด	TS1	SS22	P/LS	M	บ้านกระทุ่มล้ม	TS8
SS6	P	M	วัดบางช้างใต้	TS2	SS26	P/LS	M	วัดท่าพูด	TS10
SS8	P/LS	M	วัดดอนหวาย	TS3	SS28	LS/US	L	วัดไร่ขิงวิทยา	TS10
SS11	P/LS	M	วัดหอมเกร็ด	TS5	SS35	P/LS	M	วัดจินดาราม	TS13
SS16	P/LS	M	วัดวังน้ำขาว	TS6	SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15
SS17	LS/US	M	ปรีดารามวิทยาคม	TS6	SS40	LS/US	L	สามพรานวิทยา	TS16

Table 4.9c Data of the 18 selected sites at US level (idealized).

Bang Len (5)					Bang Len (5)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	M	บางเลนวิทยา	TB1	SB31	LS/US	S	บัวปากท่าวิทยา	TB7
SB12	LS/US	S	บางหลวงวิทยา	TB2	SB41	LS/US	S	สถาพรวิทยา	TB11
SB18	P/LS	S	วัดบึงลาดสวาย	TB3					
Nakhon Chai Si (6)					**Nakhon Chai Si (6)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN2	P/LS	M	วัดบางพระ	TN2	SN21	LS/US	S	เพิ่มวิทยา	TN12
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN34	LS/US	M	จิ้วรายบุญมี รังสฤษดิ์	TN21
SN17	LS/US	S	แหลมบัววิทยา	TN10	SN36	LS/US	M	ภัทรญาณวิทยา	TN22
Phutthamonthon (2)					**Phutthamonthon (2)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP9	LS/US	M	รัตนโกสินทร์ สมโภชฯ	TP3	SP10	LS/US	L	กาญจนาภิเษกฯ	TP3
Sam Phran (5)					**Sam Phran (5)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	LS/US	M	วัดเทียนดัด	TS1	SS38	LS/US	M	ภ.ป.ร.ราช วิทยาลัยฯ	TS15
SS17	LS/US	S	ปรีดาราม วิทยาคม	TS6	SS40	LS/US	M	สามพราน วิทยา	TS16
SS28	LS/US	L	วัดไร่ขิงวิทยา	TS10					

4.3.2 Efficiency assessment in term of the service area

Efficiencies of the new school maps presented in Figures 4.10a-4.10e, 4,11a-4.11c, and 4.12a-4.12c were evaluated in terms of the service area, service loading (SL), and average travel distance to school, under the prescribed criteria and the results are reported in Tables 4.10 and 4.11.

Table 4.10 School efficiency in term of the service area (idealized).

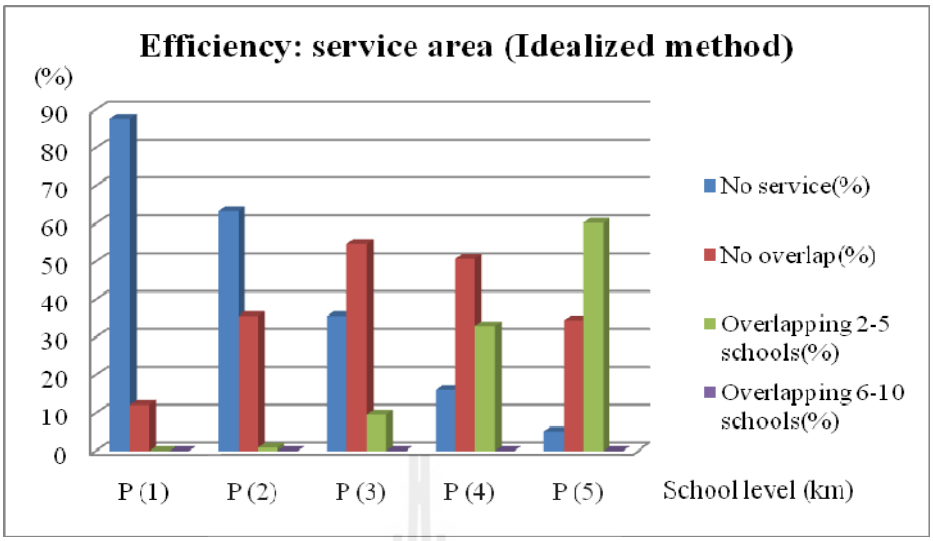
Level	Distance limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (50)	1	389	87.81	54	12.19	-	-	-	-
	2	281	63.43	158	35.67	4	0.90	-	-
	3	158	35.67	242	54.63	43	9.71	-	-
	4	72	16.25	225	50.79	146	32.96	-	-
	5	23	5.19	153	34.54	267	60.27	-	-
LS (50)	3	168	37.92	226	51.02	49	11.06	-	-
	5	28	6.32	173	39.05	239	53.95	3	0.68
	7	1	0.23	60	13.54	330	74.49	52	11.74
US (18)	5	209	47.18	146	32.96	88	19.86	-	-
	7	81	18.28	207	46.73	155	34.99	-	-
	10	18	4.06	130	29.35	272	61.40	23	5.19

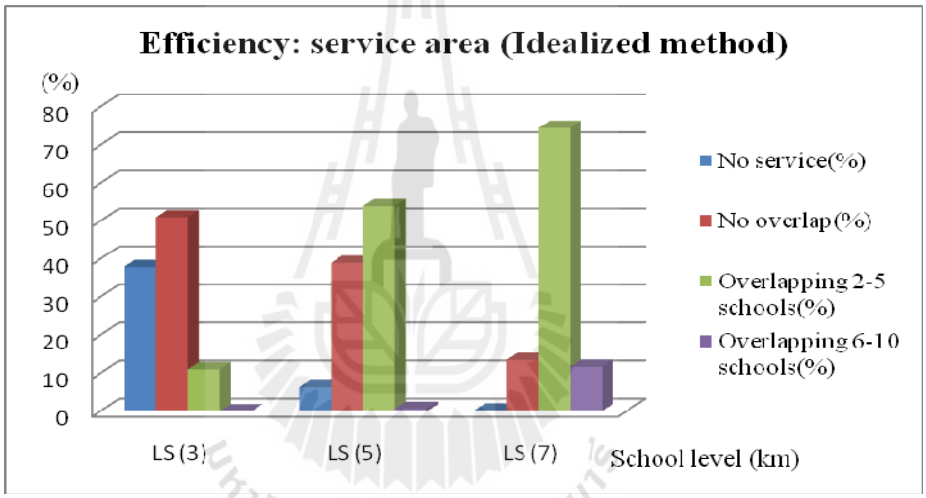
Note: VIL ≡ number of villages, % ≡ percent of total villages (443).

Table 4.11 School efficiency in term of the service area at district level (idealized).

BLN	Limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (23)	3	57	31.67	114	63.33	9	5.00	-	-
LS (20)	3	72	40.00	107	59.44	1	0.56	-	-
US (5)	5	117	65.00	63	35.00	-	-	-	-
NCS	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	%	VIL	%	VIL	%	VIL	%
P (12)	3	30	27.78	61	56.48	17	15.74	-	-
LS (12)	3	30	7.78	52	48.15	26	24.07	-	-
US (6)	5	18	16.67	58	53.70	32	29.63	-	-
PMT	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	%	VIL	%	VIL	%	VIL	%
P (4)	3	12	66.67	6	33.33	-	-	-	-
LS (6)	3	8	44.44	8	44.44	2	11.11	-	-
US (2)	5	6	33.33	7	38.89	5	27.78	-	-
SPR	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	%	VIL	%	VIL	%	VIL	%
P (11)	3	60	43.80	59	43.07	18	13.14	-	-
LS (12)	3	57	41.61	60	43.80	20	14.60	-	-
US (5)	5	48	35.04	60	43.80	29	21.17	-	-

Note: VIL ≡ number of villages, % ≡ Percent of total villages at each district.





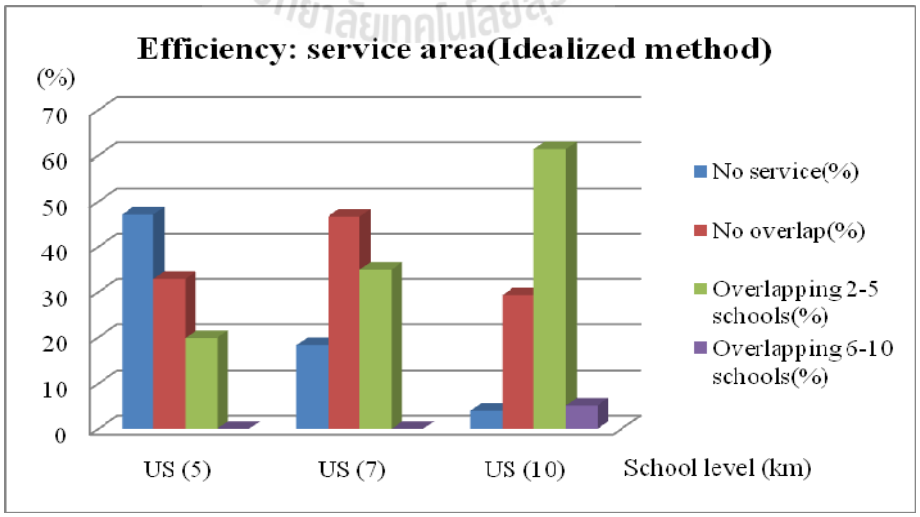


Figure 4.13 School efficiency in term of service area from Table 4.10 (idealized situation).

Tables 4.10, 4.11 and Figure 4.13 are described efficiency of school locations (at all 3 school levels) from idealized method in term of associated service area as presented in Figures 4.10a-4.10e, 4.11a-4.11c, and 4.12a-4.12c. It is obvious that numbers of villages without service are significantly reduced when distance limits of the associated service area increase. For example, at P level, percentage of the no-service village reduces from about 87.81%, 35.67%, and 5.19% when distance limit rises from 1, 3, and 5 km, respectively (Figures 4.10a, 4.10c, and 4.10e). Similar trends occur at the LS and US level also. However, the expansion of defined service area may result in notably higher amount of service-overlapping villages; e.g. at P level, number of the overlapped village increases from about 0%, 9.71%, and 60.27% when the distance limit changes from 1, 3, and 5 km, respectively. Most overlapped villages are under service of 2-5 schools simultaneously but if a distance limit increases (e.g. ≥5 km) the overlapping service of more than 5 schools are more visible.

At the distance limits of 3 km (for P and LS levels) and 5 km (for US level) that are in favor by the state policy, the no-service areas become 35.67%, 37.92%, and 47.18%, while overlapped areas become 9.71%, 11.06%, and 19.86%, respectively. These numbers indicate that the selected primary schools can provide services to about 2/3 of all villages and about 1/3 of them are still off service (at 3 km distance limit). This number is notably higher than the present situation (at 11.06%). But the overlapped villages of about 9.71% infer the relatively well-placed locations of the selected schools. This number decreases dramatically from one obtained from idealized method (49.43%) due to great reduction in number of the relevant primary schools (from 127 to 50).

Similarly, at distance limits of 3 km (LS level) and 5 km (US level), numbers of the no-service villages are about 1/3 and 1/2 of the total village numbers, respectively. These results mean that the preferred number and/or positions of the LS and US schools are still not sufficient, or appropriate, to contribute school services to most villages residing in the area (at these distance limits) as primarily required.

And like being discussed earlier in Section 4.2.1, the possible solutions for this situation are the increases in number of the LS and US schools and/or values of distance limit. For examples, if distance limits become 5 km (for LS level) and 7 km (for US level), numbers of the no-service villages shall decrease to be 6.32% and 18.28%, respectively, while overlapped villages shall become 54.63% and 34.99%, respectively. These resulted numbers should justify substantial need to reduce numbers of the no-service villages if the notable increase in numbers of the overlapped villages does not raise much concern. Actually, distance limits of 5 km (for LS level) or 7 km (for US level) should be plausible nowadays if we assume that students at LS/US levels can travel to schools by cycling or taking some kind of the motor vehicles (but not by walking).

4.3.3 Efficiency assessment in term of the service loading

As stated earlier, to determine the SL value and calculate potential school scale for a chosen school location (on the new school maps), all current students of neglected schools are assumed to become members of chosen site that locates closest to them only. And, as usual, the crucial criteria imposed in calculating average travel distance are that each student can attend only one school situating closest to their residences (assumed to be at the village location) and there is no limit on the used travel distance.

From Table 4.12, it was found that higher distance limit leads to lower number of SL as expected (at all school levels). And at preferred distance limits of 3 km (for P and LS levels) and 5 km (for US level), numbers of the low SL schools (L) become 3 schools (6.0%), 13 schools (26.0%), and 0 schools (0%), respectively, while numbers of the very high SL schools (VH) become 14 schools (28.0%), 9 schools (18.0%), and 5 schools (27.78%), respectively.

Table 4.12 School efficiency in term of the service loading (idealized).

SL level	P level					LS level			US level		
	1 km	**2 km**	**3 km**	**4 km**	**5 km**	**3 km**	**5 km**	**7 km**	**5 km**	**7 km**	**10 km**
L (critical)	-	-	3	6	17	13	25	30	-	1	4
ML (normal)	-	2	6	21	24	9	7	8	1	3	3
MH (normal)	1	3	11	13	7	7	5	1	3	4	5
H (concerned)	1	7	14	4	1	1	2	-	5	5	2
VH (critical)	30	34	14	6	1	9	-	-	5	1	-
Other	18	4	2	-	-	11	11	11	4	4	4
Total schools	50	50	50	50	50	50	50	50	50	50	18

Note: 1. L ≡ Low, ML ≡ Medium low, MH ≡ Medium high, H ≡ High, VH ≡ Very high.

2. Other ≡ Cases with AOT or POT = 0.

Table 4.13 Average SL values for different categories of the school scales (idealized).

Schoo lscale	P level				LS level			US level		
	1 km	**2 km**	**3 km**	**5 km**	**3 km**	**5 km**	**7 km**	**5 km**	**7 km**	**10 km**
S	-	-	-	80.75	52.1	30.9	15.8	-	-	-
M	788.3	506	185.9	69.01	120.1	54.1	28.5	81.5	39.8	23.1
L	1135.5	293.1	190.1	84.2	430.1	83.6	55.8	89.8	60.6	30.9
VL	1004.3	340.3	202.3	80.4	52.1	30.9	15.8	111	51.8	31.8

Note: 1. Cases with AOT or POT = 0 are not included.

2. School scale: S ≡ Small (1-120 students), M ≡ Medium (121-600 students),

L ≡ Large (601-1500 students), VL ≡ Very large (>1500 students).

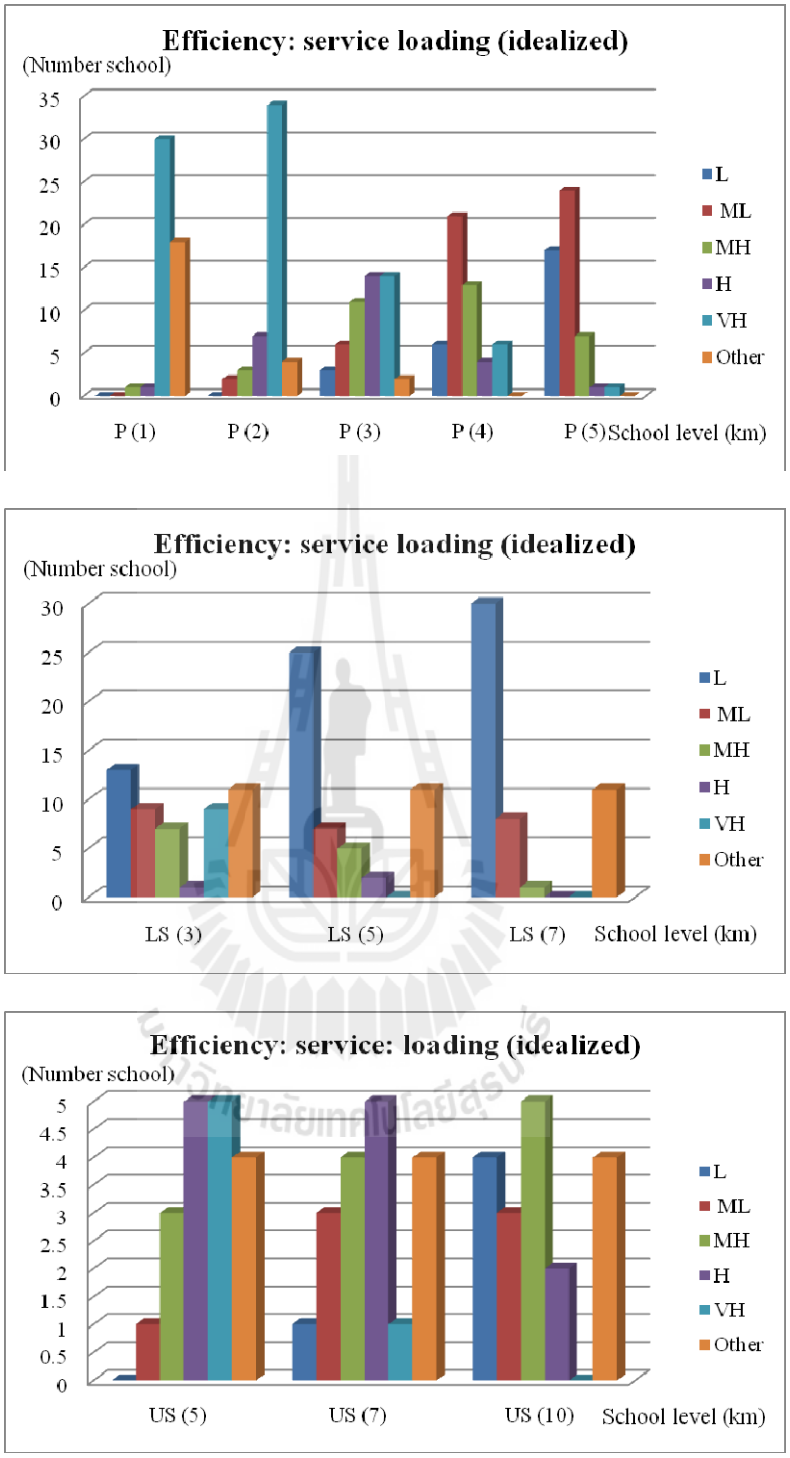


Figure 4.14 School efficiency in term of service loading from Table 4.12 (idealized situation).

Table 4.14 School efficiency in term of the service loading at district level (idealized).

BLN	Limits (km)	L		ML		MH		H/VH		Other	
		SCH	%	SCH	%	SCH	SCH	SCH	%	SCH	%
P (23)	3	-	-	4	17.39	2	2	13	56.52	2	8.70
LS (20)	3	3	15.00	1	5.00	8	8	4	20.00	8	40.00
US (5)	5	-	-	1	20.00	1	1	1	20.00	1	20.00
NCS	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**%**	**%**	**SCH**	**%**	**SCH**	**%**
P (12)	3	2	16.67	1	8.33	5	41.67	2	16.67	-	-
LS (12)	3	5	41.67	3	25.00	2	16.67	1	8.33	1	8.33
US (6)	5	1	16.67	3	50.00	-	-	-	-	2	33.33
PMT	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**%**	**%**	**SCH**	**%**	**SCH**	**%**
P (4)	3	-	-	-	-	-	-	4	100.0	-	-
LS (6)	5	2	33.33	-	-	-	-	3	50.00	1	16.67
US (2)	5	-	-	-	-	1	50.00	1	50.00	-	-
SPR	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (11)	3	1	9.09	1	9.09	3	27.27	6	54.55	-	-
LS (12)	5	3	25.00	5	41.67	1	8.33	2	16.67	1	8.33
US (5)	5	1	20.00	1	20.00	2	40.00	-	-	1	20.00

Note: 1. SCH ≡ number of schools, % ≡ percent of total schools at each district (at a specific level).

2. Other ≡ Cases with AOT or POT = 0.

These results indicate that at these distance limits; percentages of the considered school with low SL values drop dramatically from the present scenario at P level (from 33.86 to 6%) but they are rather comparable at the LS level (from 33.33 to 26%), and noticeably decreased at the US level (from 12.85 to 0%). This should be due to large drop in number of the functioning primary schools (from 127 to 50) where

most of the discarded ones are the small-scale schools (according to criteria described in Section 3.2.3). Relatively high proportion in number of schools with moderate/high/very-high SL values (at all levels) indicates capability of the used idealized technique to abolish the relatively low SL ones and to encourage higher service capability to most functioning schools that still exist in the study area (from the idealized method).

4.3.4 Efficiency assessment in term of the travel distance to school

As mentioned earlier, the criteria in calculating average travel distance are that a student can attend only one school situating closest to their residences (assumed to be at the corresponding village location) and there is no limit on the travel distance of a student (similar to ones required in the p-median model). Results of the analysis are reported in Table 4.8 which indicate that average travel distances of the students (from the idealized method) are 2.46 km (at P level), 2.40 km (at LS level), and 4.19 km (at US level). The average value of 2.46 km (with maximum of 7.78 km) at P level is notably higher when compared to those before applying the idealized method (average 1.62 km and maximum 5.02 km) due to great decrease in number of the functioning schools (from 127 to 50). However, these numbers should still be reasonably acceptable for the cycling or motor-vehicle using modes of travelling to school (for the students). However, it should be noted that, at P level, many students may prefer walking to schools along some specific shorter paths that do not include in the available road network maps. This could result in the potential shorter travel distance to school (average value) than one being obtained by using formal road network alone.

The average values of about 2.40 km (with maximum value of 7.58 km) at the LS level, and 4.19 km (with maximum value of 12.83 km) at US level, are rather comparable to those obtained before applying the idealized method (average 2.66 km/maximum 8.33 km at LS level and average 4.80 km/maximum 13.16 km at the US level). These should be due to similar numbers of considered schools before and after applying the idealized method (39 to 50 at LS level and 16 to 18 at US level) where most existing old schools at both levels (except ones with rather low SL values) were still functioned after applying the idealized method. This makes school's location maps (before and after applying the idealized method) do not look much different from each other (at each school's level) (see Figures 4.7a-4.7c and 4.8a-4.8c for comparison at LS/US levels, respectively).

As discussed earlier in this Section, basic assumption of students traveling to schools along the road network might be not valid in some cases as many students may take shorter routes to attend their school which are not included in the used road network map (especially at the P and LS levels that walking and cycling are popular). This could introduce potential shorter travel distance to school (average value) than the one being obtained by using formal road network alone. Results of the school efficiency (in term of the travel distances) reported here should be more applicable if the school's zoning policy is fully enforced in Thailand at the corresponding school levels.

4.4 Efficiency Comparison between Present and Idealized Scenarios

Results obtained from previous works reported in Sections 4.2 (present scenario) and 4.3 (idealized scenario) were compared in Tables 4.8 and 4.15. These are:

(1) number of the functioning schools,

(2) amount of the no-service and overlapped areas (village-based),

(3) number of the low SL schools, and

(4) average travel distances to school (at each school level).

It was found that in term of the functioning schools, number of preferred schools at P level drops significantly after idealize method being applied (from 127 to 50), mostly from the dissolving of most small-scale schools after applying the idealized method. On the contrary, at LS level, number increases from 39 to 50 but, at US level, they are rather comparable (from 16 to 18). Lower amount of needed schools means less running cost and better chances to improve chosen school efficiency in terms of service loading and teaching quality. Maps of school locations for each scenario are given in Figures 4.15a-4.15c.

In term of the no-service area, at P level, present situation did notably better than the idealized situation at all distance limits due to its much higher number of functioning schools (127 to 50). For examples, amounts of no-service area for present and idealized scenario at distance limit of 1, 2, and 3 km are 77.43/87.81, 40.86/63.43, and 11.06/35.67%, respectively. But the smaller number of preferred schools in the idealized method leads to much lower number of overlapped villages. For examples, these numbers at limits of 1, 2, and 3 km are 0.45/0.0, 16.48/0.90, and 49.43/9.71%, respectively.

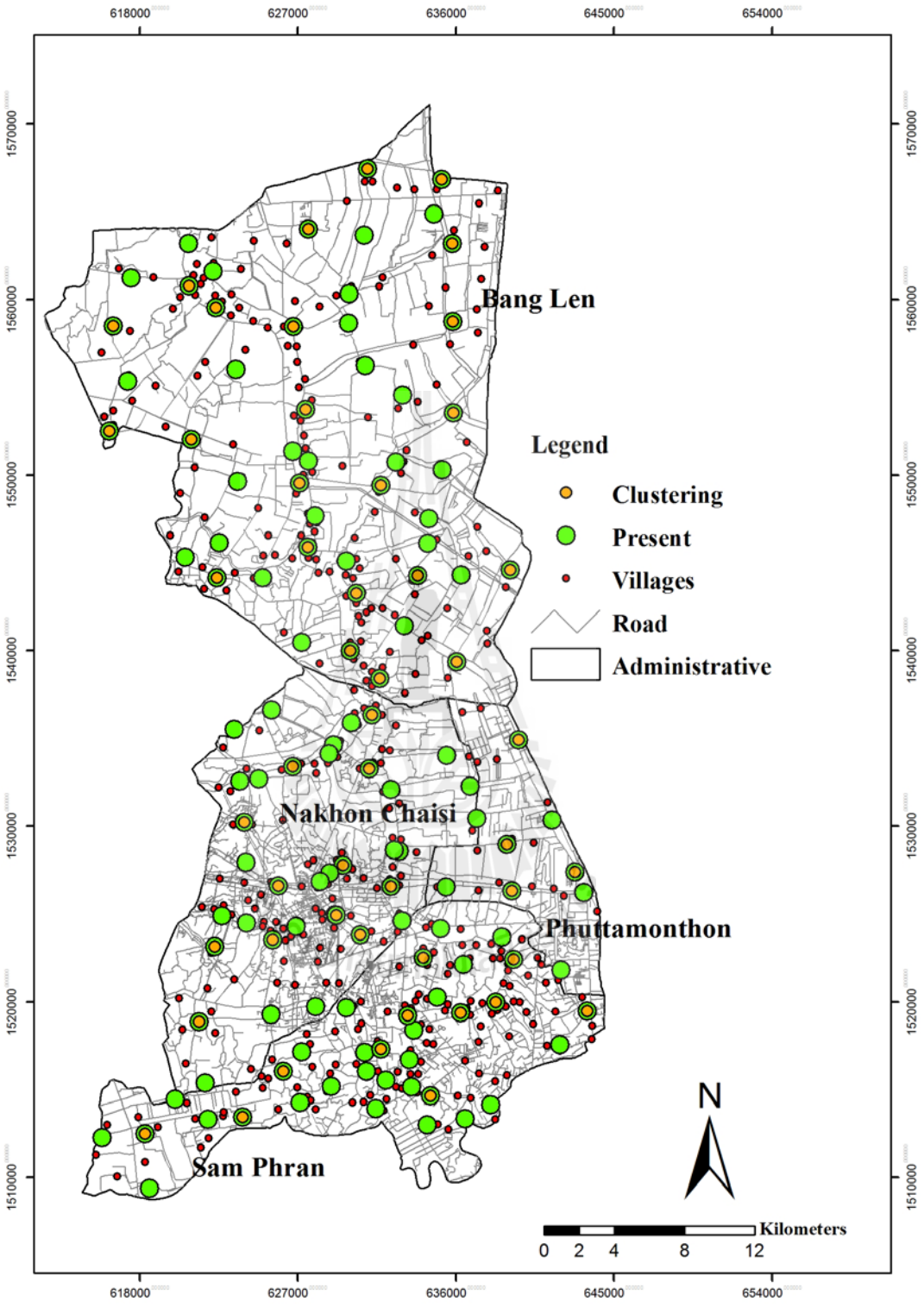


Figure 4.15a School location map at P level (present and idealized scenarios).

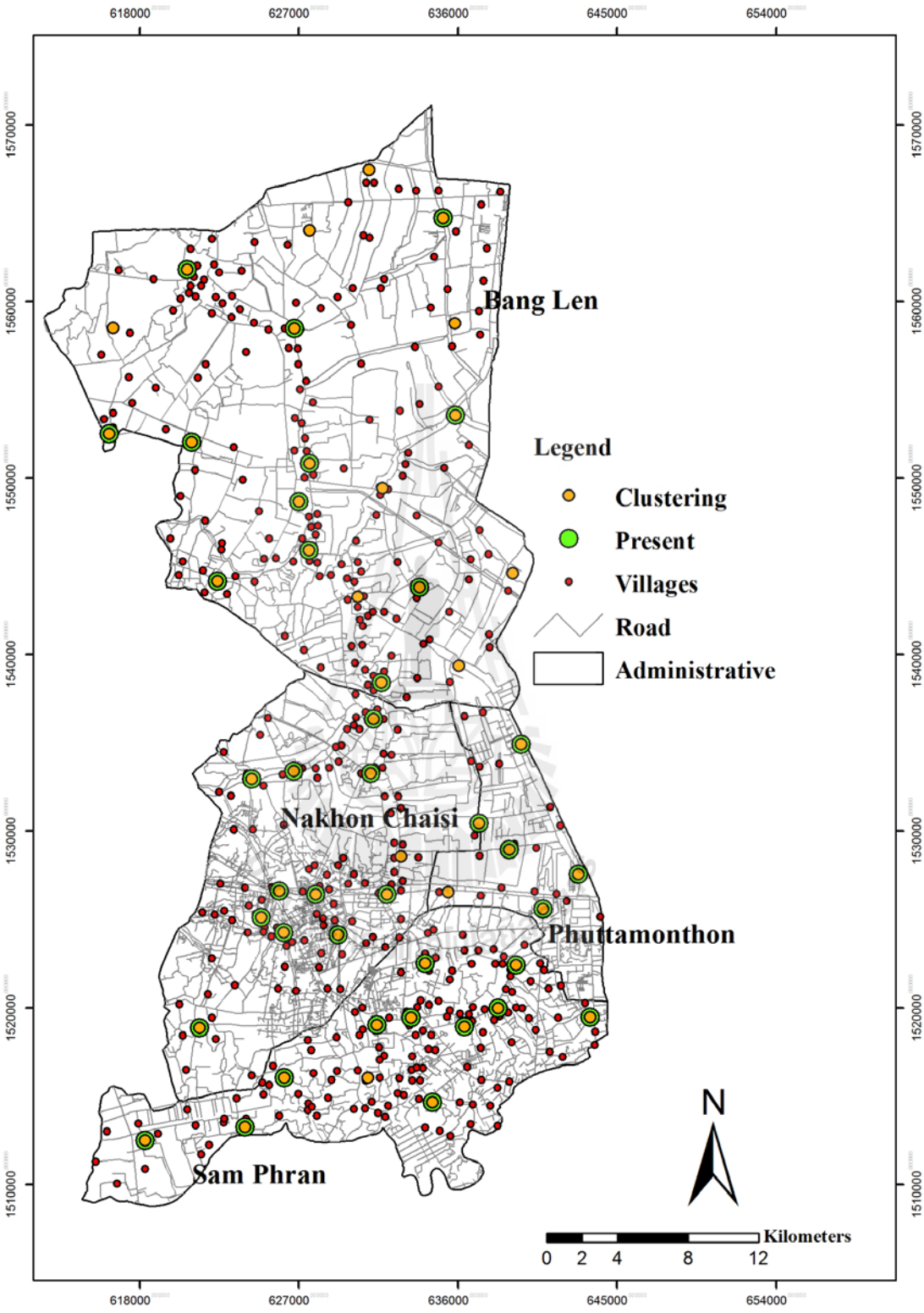


Figure 4.15b School location map at LS level (present and idealized scenarios).

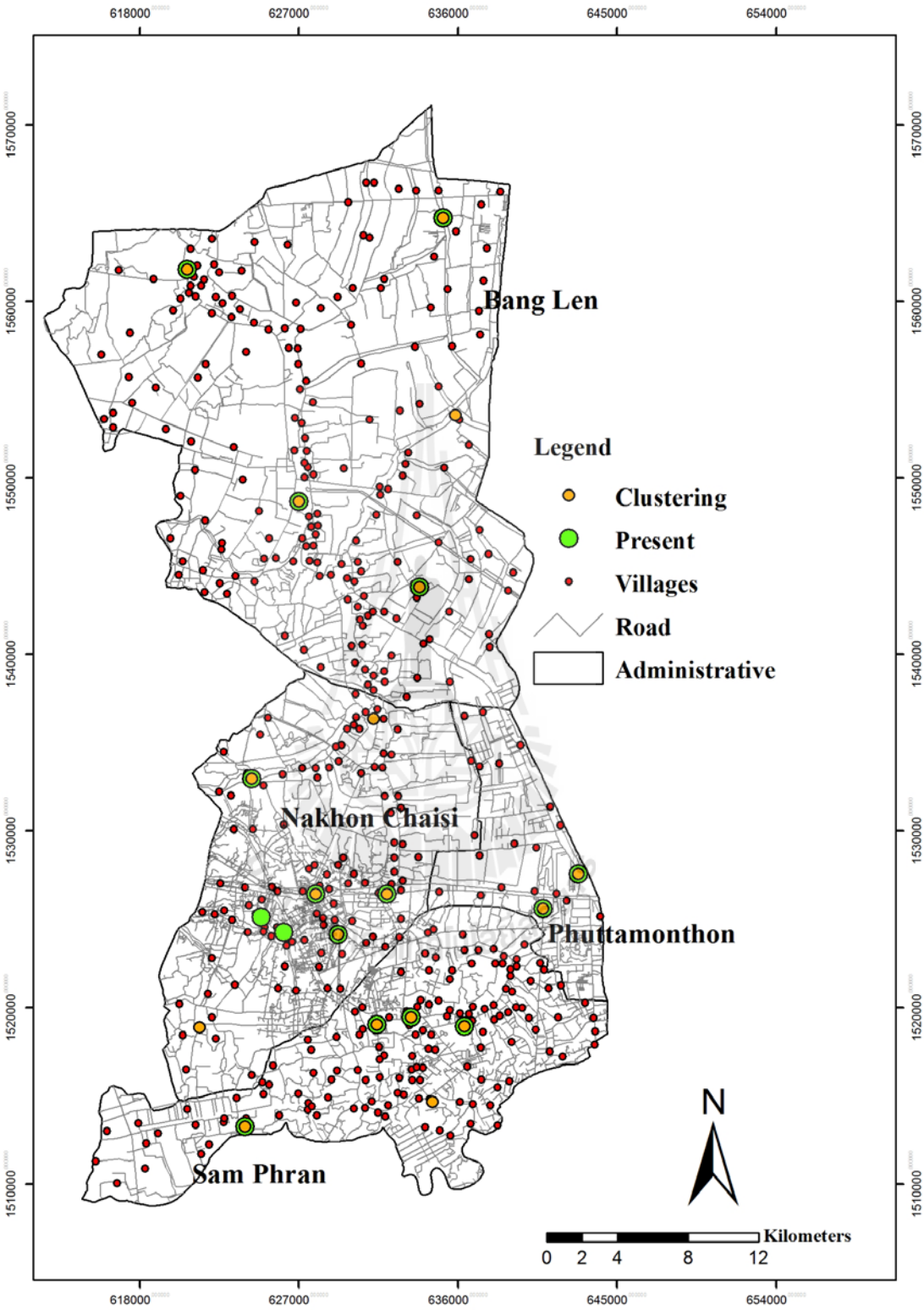
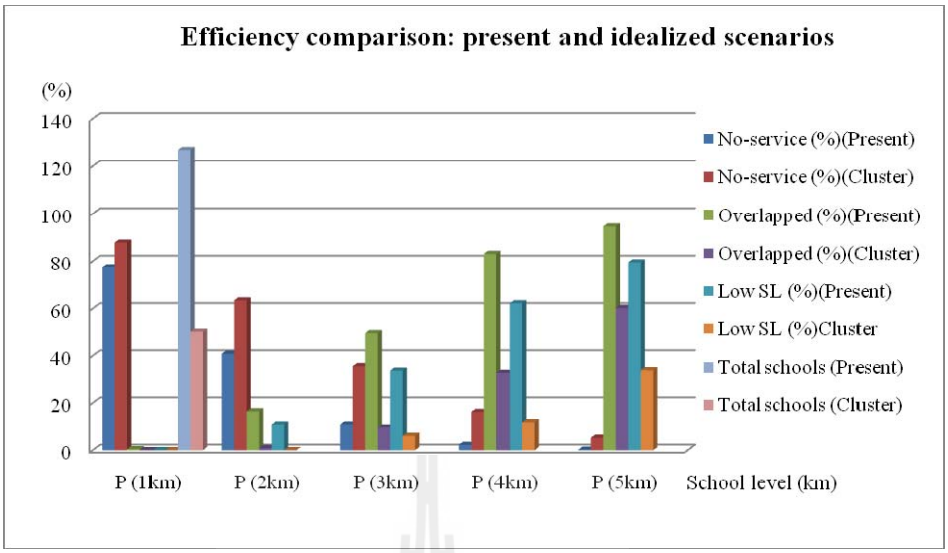


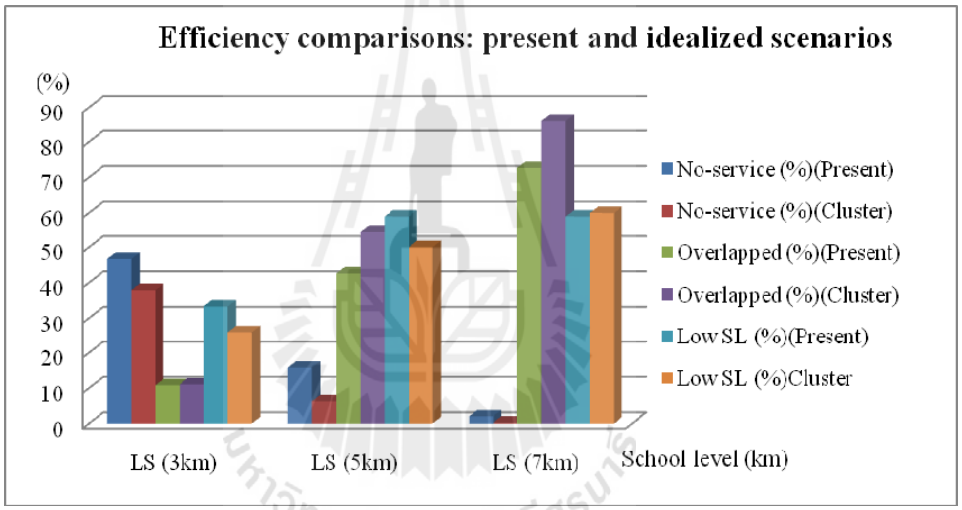
Figure 4.15c School location map at US level (present and idealized scenarios).

Table 4.15 Efficiency comparisons between present and idealized scenarios.

School level	No-service (%) (village-based)		Overlapped (%) (village-based)		Low SL (%) (school-based)		Total schools	
	Present	Idealized	Present	Idealized	Present	Idealized	Present	Idealized
P (1 km)	77.43	87.81	0.45	-	-	-		
P (2 km)	40.86	63.43	16.48	0.90	11.02	-		
P (3 km)	11.06	35.67	49.43	9.71	33.86	6.0	127	50
P (4 km)	2.26	16.25	83.07	32.96	62.20	12.0		
P (5 km)	0.23	5.19	94.58	60.27	79.53	34.0		
LS (3 km)	46.73	37.92	10.84	11.06	33.33	26.0		
LS (5 km)	15.80	6.32	42.66	54.63	58.97	50.0	39	50
LS (7 km)	2.03	0.23	72.68	86.23	58.97	60.0		
US (5 km)	53.95	47.18	17.38	19.86	12.5	-		
US (7 km)	30.93	18.28	30.48	34.99	18.75	5.56	16	18
US (10 km)	8.58	4.06	51.92	66.59	37.5	22.22		

At LS level, numbers of the no-service village drop noticeably at all used distance limits (3, 5, and 7 km) due to the moderate increase in number of the functioning schools from the idealized method (from 39 to 50). This trend was also found at the US level where number of considered schools slightly increases from 16 to 18 after applying idealized method. However, in term of overlapped area, there are rather comparable between those observed before and from the idealized method (at each distance limit of LS/US levels) with numbers of the idealized method slightly higher (at all distance limits). These results mean idealized method does not give much impact on total amount of the overlapped area but it has some significant impact on amount of the no-service area, especially at longer distance limits.





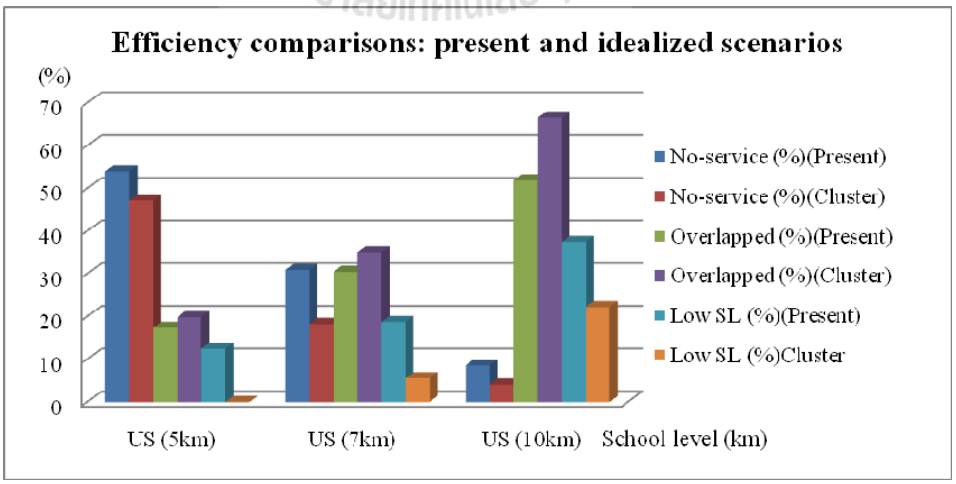


Figure 4.16 Efficiency comparisons between present and idealized scenarios (Table 4.15).

At distance limits of 3 km (for P and LS levels) and 5 km (for US level) that are preferred by state's policy, the no-service villages become 35.67%, 37.92%, and 47.18%, respectively, while overlapped villages become 9.71%, 11.06%, and 19.86%, respectively. These numbers indicate that the selected primary school locations (from the idealized method) can provide services to about 2/3 of all villages and about 1/3 of them still left out (at 3 km distance limit). But the overlapped villages of 9.71% infer the relatively well-placed locations of the preferred schools. Similarly, at distance limits of 3/5 km (LS/US level), numbers of the no-service village are about 1/3 and 1/2 of the total villages, respectively. This means the preferred number and/or positions of the LS and US schools are still not sufficient to provide service to most villages located in the study area (at these distance limits). It is therefore suggested that more schools at all levels should be placed in the study area (regarding to results of the idealized scenario) to meet some certain target of the maximum no-service area, e.g. 10-15% of the total villages. Or, the official distance limits should be extended from the ones in use at present, e.g. from 3 to 5 km at LS level, or from 5 to 7 km at US level, which will result in the much lower no-service area as follows: 37.92 to 6.32% (LS level) and 47.18 to 18.28% (US level).

In term of the number of low SL schools, it was discovered that percentage of the low SL schools at P level drops sharply in the idealized scenario at most distance limits, e.g. from 11.02 to 0.0% (2 km), 33.86 to 6.0% (3 km), and 79.53 to 34.0% (5 km). The significant drops are also observable at US level, e.g., from 12.5 to 0.0% (5 km) and 18.75 to 5.56% (7 km), but not much decrease appears at LS level, e.g., from 33.33 to 26.0% (3 km) and 58.97 to 50.0% (5 km). The large drop occurred at P level is due to lower number of the preferred primary schools (from 127 to 50) where most

of the abandoned ones are the small-scale schools. In addition, relatively high proportion of schools with moderate or high SL values indicates capability of the idealized process to abolish the relatively low SL ones and promote higher SL schools residing in the area (by the idealized method).

In term of the average travel distance, those values seen before/after applying the idealized process at LS and US levels are rather comparable, which are 2.66 km/2.40 km (at the LS level) and 4.80 km/4.89 km (at the US level) due mainly to the similar numbers of preferred schools before/after applying the idealized process. But at P level, average distance is substantially higher after applying the idealized process (from 1.62 to 2.46 km) due to great drop in number of P schools after applying the idealized process (from 127 to 50). At this stage, it can primarily conclude from the obtain results that the idealized method introduces considerably longer travel distance for students at the P level due to significantly lower number of functioning schools (from 127 to 50). But it does not have much impact on average travel distances of students at the LS and US levels due mainly to the similarity in both number and location pattern of schools (at each level) before and after idealized algorithm taking place.

The found value of 2.46 km at P-level should be reasonably acceptable for cycling modes of travelling to school, and values of 2.40 and 4.89 km (at LS and US levels) are rather practical for the cycling and motor-vehicles-based modes of travelling for students at these levels in the study area.

CHAPTER V

APPLICATIONS OF P-MEDIAN AND GRAVITY P-MEDIAN MODELS

This chapter reports main results obtained from applications of the p-median and gravity p-median models to school mapping analysis in the study area. In both cases, the optimum school maps (at each school level) were produced first under some prior criteria of the used models. Then efficiencies in terms of the service area, service loading, and average travel distance were examined for the p-median school maps, and in term of the travel distance for the gravity p-median school map. The gain results were subsequently compared with those from the idealized method formerly described in Chapter IV.

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5.1 Application of P-Median Model

As stated in Chapter II, an ultimate purpose of the p-median model is to determine specific set of the service locations (from a number of given potential sites) that provides the least total travel distance for customers assumed to situate at the given demand points. In this case, several potential school locations within the study area were identified based on prior criteria described in Section 3.2.3(2) where in priority is given to the appropriate existing schools that are not locate too close to each other and to villages or tambons with high population density. Numbers of the

potential sites and the preferred school sites (at each school level) are as described in Table 3.4.

5.1.1 Formulation of optimum school maps

Table 5.1 presents results of the p-median application at district level wherein the five lowest values of the total (and average) travel distance to school at each considered district are described while Tables 5.2a-5.2c provides details of the chosen school locations for the optimum case of the lowest travel distance referred to in Table 5.1 (for each district). Then, associated school maps for the optimum case (and the corresponding service areas) at each school level were constructed as illustrated in Figures 5.1a-5.1e (P level), 5.2a-5.2c (LS level), and 5.3a-5.3c (US level) and their efficiencies were subsequently evaluated.

From Table 5.1, it can be seen that average travel distance values for the 5 lowest cases (for each school level) are just slightly different from each other. This means any of them could be used as a possible solution if only the average distance result is concerned. However, values of the lowest travel distance to school among the relevant districts are significantly different at each school level. For P level, the highest value of 2.51 km was found at Bang Len District and the lowest value of 1.60 km was found at the Sam Phran District. This trend is also seen at the LS level with average distance value of 2.52 km at the Bang Len District and 1.65 km at the Sam Phran District. However, at the US level, the highest value of 4.32 km appears at Phutthamonthon District and the lowest values of 2.7-2.8 km were found for the rest. These results indicate that traveling at P and LS levels are most severe at the Bang Len District with average distance of more than 2.5 km. This might be due to its large area coverage and low population density of the area (Table 1.1). But at US level, the most

severe situation is at the Phutthamonthon District which should be due mainly to a low number of school available (just only 1).

Table 5.1 Lowest values of the average travel distance in 2007 (p-median method).

Order (P)	Bang Len		Nakhon Chai Si		Phutthamonthon		Sam Phran	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	17132.72	2.51	18369.53	2.29	4362.97	1.67	22691.90	1.60
2	17235.72	2.53	18471.03	2.30	4613.73	1.77	22814.87	1.61
3	17529.72	2.56	18592.53	2.31	4996.63	1.91	22964.52	1.62
4	17463.31	2.56	18887.06	2.31	4999.59	1.91	23087.49	1.63
5	17543.06	2.57	18945.42	2.32	5360.23	2.05	23159.29	1.63
Order (LS)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	9869.06	2.52	10144.19	2.30	2437.78	1.70	12874.99	1.65
2	9918.16	2.54	10178.31	2.31	2788.64	1.95	13108.73	1.68
3	10016.74	2.56	10220.60	2.32	3038.23	2.12	13114.51	1.68
4	10042.12	2.57	10634.45	2.37	3041.15	2.13	13181.57	1.69
5	10078.84	2.58	10755.02	2.40	3091.77	2.16	13229.58	1.70
Order (US)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	11670.84	2.81	12765.76	2.79	5805.29	4.32	20320.97	2.78
2	11681.68	2.81	12935.85	2.82	5839.87	4.35	20388.56	2.79
3	11719.81	2.82	12939.21	2.83	6954.62	5.18	20643.45	2.82
4	11733.77	2.82	13010.37	2.84	-	-	20843.78	2.85
5	11742.75	2.83	13023.33	2.84	-	-	20912.65	2.86

Note: 1. Total ≡Total travel distance (in km), Average≡ Average travel distance per student (in km).

Table 5.2a Information of 50 selected sites at P level (p-median).

Bang Len (25)					Bang Len (25)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB2	P	M	วัดเกษมสุริยัมนาจ	TB1	SB30	P	M	วัดบัวหวั่น	TB7
SB3	P	M	บ้านบางเลน	TB1	SB34	P/LS	M	วัดลานคา	TB8
SB4	P/LS	M	บ้านประตูน้ำพระพิมล	TB1	SB36	P	M	วัดศิลามูล	TB9
SB11	P	L	วัดบางหลวง	TB2	SB39	P	M	วัดเวฬุวนาราม	TB11
SB14	P	M	บ้านคลองพระมอพิสัย	TB3	SB40	P	L	วัดลำพญา	TB11
SB16	P	M	วัดรางกำหยาด	TB3	SB44	P	M	วัดสว่างอารมณ์	TB12
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB46	P	M	วัดบัวปากท่า	TB13
SB19	P	M	วัดเกาะแรต	TB4	SB47	P	L	วัดนิลเพชร	TB13
SB20	P/LS	M	ตลาดเกาะแรต	TB4	SB48	P	S	บ้านไผ่ล้อม	TB14
SB21	P/LS	M	วัดบางปลา	TB4	SB49	P/LS	M	วัดไผ่หูช้าง	TB14
SB23	P	M	วัดสุขวัฒนาราม	TB5	SB52	P	M	วัดเกษตราราม	TB15
SB25	P	M	วัดผาสุการาม	TB6	SB53	P/LS	M	วัดโพธิ์	TB15
SB26	P	M	วัดบางไผ่นารถ	TB6					
Nakhon Chai Si (12)					**Nakhon Chai Si (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN8	P/LS	M	วัดห้วยพลู	TN7	SN22	P	M	วัดจิ้วราย	TN13
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN25	P	L	วัดไทร	TN15
SN10	P	L	วัดประชานาถ	TN9	SN26	P	L	วัดน้อย	TN16
SN12	P/LS	L	วัดศรีมหาโพธิ	TN9	SN28	P	M	วัดท่าตำหนัก	TN17
SN19	P	M	วัดลานตากฟ้า	TN11	SN30	P	L	วัดกกตาล	TN19
SN20	P	L	วัดกลางบางแก้ว	TN12	SN39	P	L	วัดใหม่สุคนธาราม	TN23
Phutthamonthon (3)					**Phutthamonthon (3)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	L	วัดมะเกลือ	TP1	SP8	P	VL	พระตำหนักฯ	TP3
SP5	P/LS	L	บ้านคลองโยง	TP2					
Sam Phran (10)					**Sam Phran (10)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	L	วัดเทียนดัด	TS1	SS22	P/LS	VL	บ้านกระทุ่มล้ม	TS8
SS6	P	L	วัดบางช้างใต้	TS2	SS24	P	L	บ้านคลองลัดอ้อมใหญ่	TS9
SS8	P/LS	VL	วัดดอนหวาย	TS3	SS26	P/LS	VL	วัดท่าพูด	TS10
SS11	P/LS	L	วัดหอมเกร็ด	TS5	SS35	P/LS	L	วัดจินดาราม	TS13
SS16	P/LS	L	วัดวังน้ำขาว	TS6	SS39	P	L	วัดสรรเพชญ	TS16

Note: TAM ≡ Tambon, Scale ≡ Resulted school scale in the p-median scenario.

Table 5.2b Information of 50 selected sites at LS level (p-median).

Bang Len (25)					Bang Len (25)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB2	P	M	วัดเกษมสุริยัมนาจ	TB1	SB30	P	M	วัดบัวหวั่น	TB7
SB5	LS/US	L	บางเลนวิทยา	TB1	SB31	LS/US	M	บัวปากท่าวิทยา	TB7
SB12	LS/US	M	บางหลวงวิทยา	TB2	SB34	P/LS	M	วัดลานคา	TB8
SB16	P	M	วัดรางกำหยาด	TB3	SB36	P	M	วัดศิลามูล	TB9
SB17	P	M	ตลาดรางกระทุ่ม	TB3	SB40	P	M	วัดลำพญา	TB11
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB41	LS/US	M	สถาพรวิทยา	TB11
SB19	P	M	วัดเกาะแรต	TB4	SB44	P	S	วัดสว่างอารมณ์	TB12
SB20	P/LS	S	ตลาดเกาะแรต	TB4	SB46	P	S	วัดบัวปากท่า	TB13
SB21	P/LS	S	วัดบางปลา	TB4	SB48	P	S	บ้านไผ่ล้อม	TB14
SB23	P	S	วัดสุขวัฒนาราม	TB5	SB49	P/LS	S	วัดไผ่หูช้าง	TB14
SB25	P	M	วัดผาสุการาม	TB6	SB52	P	M	วัดเกษตราราม	TB15
SB26	P	M	วัดบางไผ่นารถ	TB6	SB53	P/LS	M	วัดโพธิ์	TB15
SB29	P	M	ตลาดเจริญสุข	TB7	-	-	-	-	-
Nakhon Chai Si (12)					**Nakhon Chai Si (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN1	L	M	ปรกแก้ววิทยา	TN1	SN27	LS/US	-	พลอยจาตุรจินดา	TN16
SN8	P/LS	M	วัดห้วยพลู	TN7	SN33	P/LS	L	วัดศรีษะทอง	TN20
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	TN14	-	-	ต.พะเนียด	TN14
SN12	P/LS	M	วัดศรีมหาโพธิ	TN9	TN17	-	-	ต.ท่าตำหนัก	TN17
SN17	L	M	แหลมบัววิทยา	TN10	TN18	-	M	ต.ไทยาวาส	TN18
SN21	L	M	เพิ่มวิทยา	TN12	TN24	-	-	ต.วัดสำโรง	TN24
Phutthamonthon (3)					**Phutthamonthon (3)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	M	วัดมะเกลือ	TP1	SP10	P/LS	VL	กาญจนาภิเษกฯ	TP3
SP5	P/LS	S	บ้านคลองโยง	TP2	-	-	-	-	-
Sam Phran (10)					**Sam Phran (10)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS11	P/LS	L	วัดหอมเกร็ด	TS5	TS2	-	M	ต.บางช้าง	TS2
SS17	LS/US	M	ปรีดารามวิทยาคม	TS6	TS7	-	-	ต.คลองใหม่	TS7
SS22	P/LS	L	บ้านกระทุ่มล้ม	TS8	TS9	-	VL	ต.อ้อมใหญ่	TS9
SS35	P/LS	L	วัดจินดาราม	TS13	TS11	-	M	ต.สามพราน	TS11
SS40	LS/VS	L	สามพรานวิทยา	TS16	TS12	-	L	ต.ทรงคนอง	TS12

Table 5.2c Information of 18 selected sites at US level (p-median).

Bang Len (9)					**Bang Len (9)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	L	บางเลนวิทยา	TB1	TB6	-	-	ต.บางไทรป่า	TB6
SB31	LS/US	S	บัวปากท่าวิทยา	TB7	TB9	-	-	ต.หินมูล	TB9
SB41	LS/US	S	สถาพรวิทยา	TB11	TB13	-	-	ต.นิลเพชร	TB13
TB4	-	-	ต.บางปลา	TB4	TB15	-	-	ต.ไทรงาม	TB15
TB5	-	-	ต.บางระกำ	TB5					
Nakhon Chai Si (4)					**Nakhon Chai Si (4)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN17	LS/US	S	แหลมบัว	TN10	SN27	LS/US	S	พลอยจาตุรจินดา	SN27
SN21	LS/US	M	เพิ่มวิทยา	TN12	TN7	-	-	ต.ห้วยพลู	TN7
Phutthamonthon (1)					**Phutthamonthon** (1)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP10	US	L	กาญจนาภิเษกฯ	TP3					
Sam Phran (4)					**Sam Phran (4)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS17	LS/US	S	ปรีดารามวิทยาคม	TS6	SS40	LS/US	L	สามพราน	TS15
SS28	LS/US	L	ไร่ขิง	TS3	TS15	-	-	ต.บ้านใหม่	TS1

มหาวิทยาลัยเทคโนโลยีสุรนารี

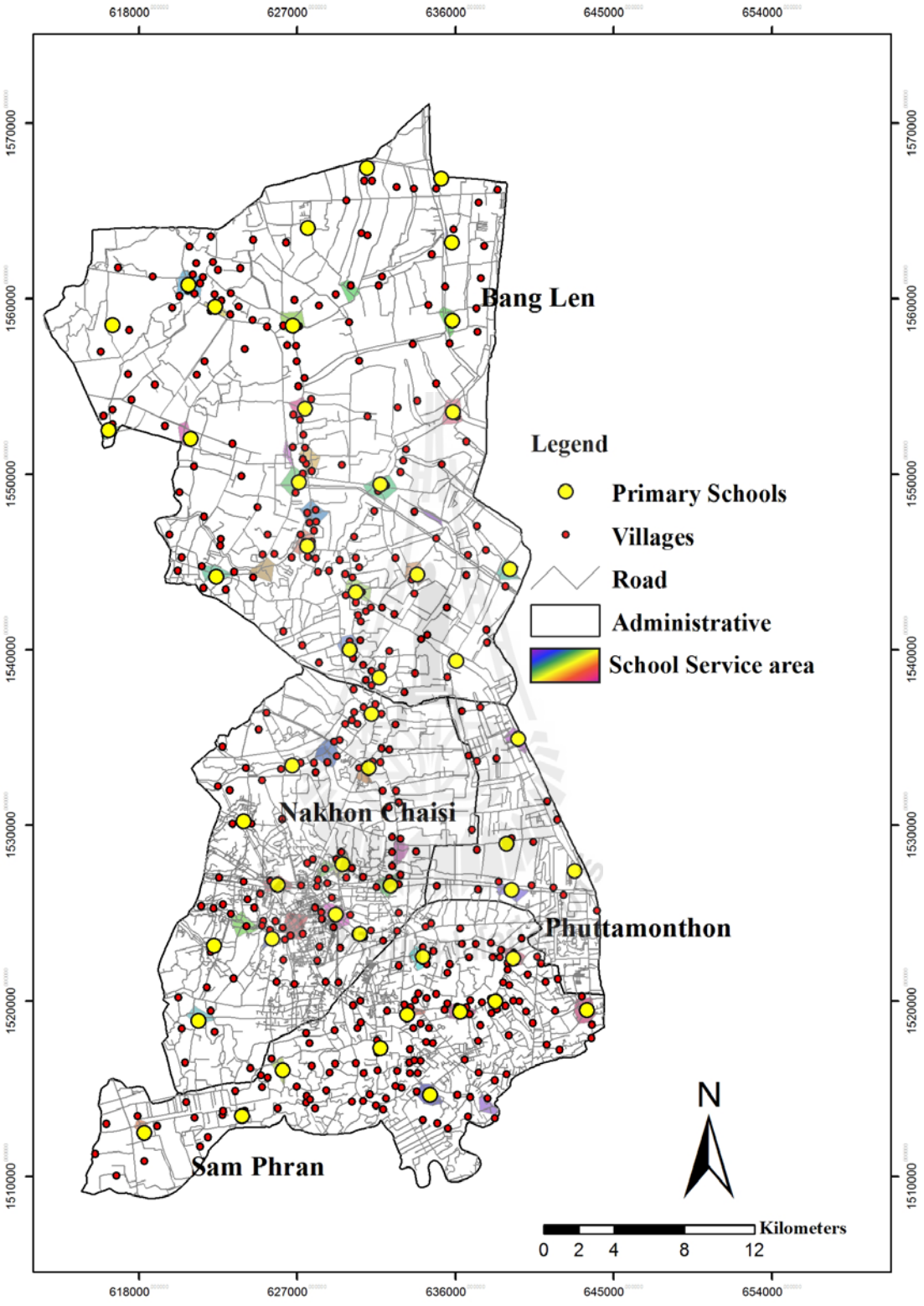


Figure 5.1a Map of school service areas (1 km limit) at P level in 2007 (P-median).

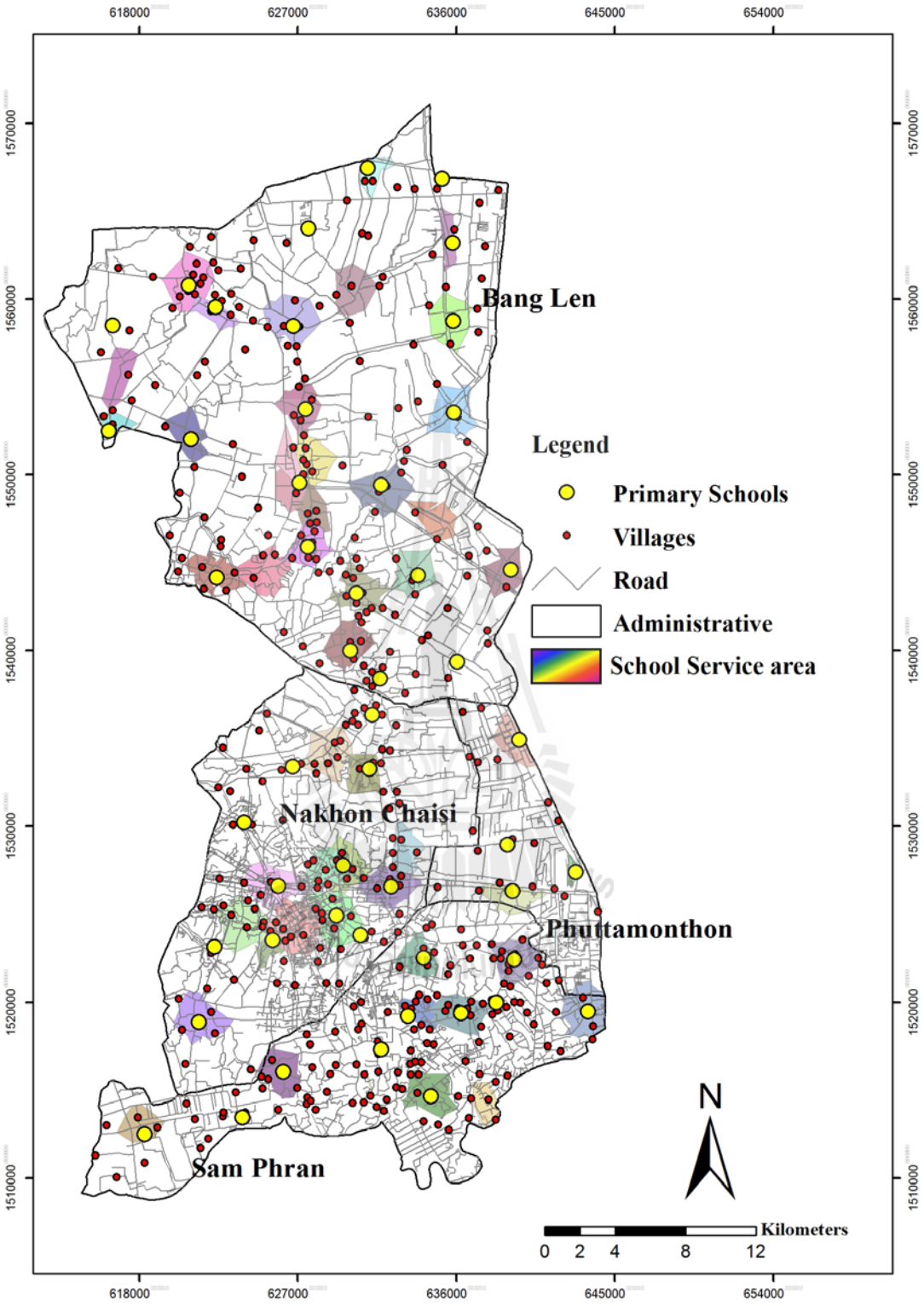


Figure 5.1b Map of school service areas (2 km limit) at P level in 2007 (P-median).

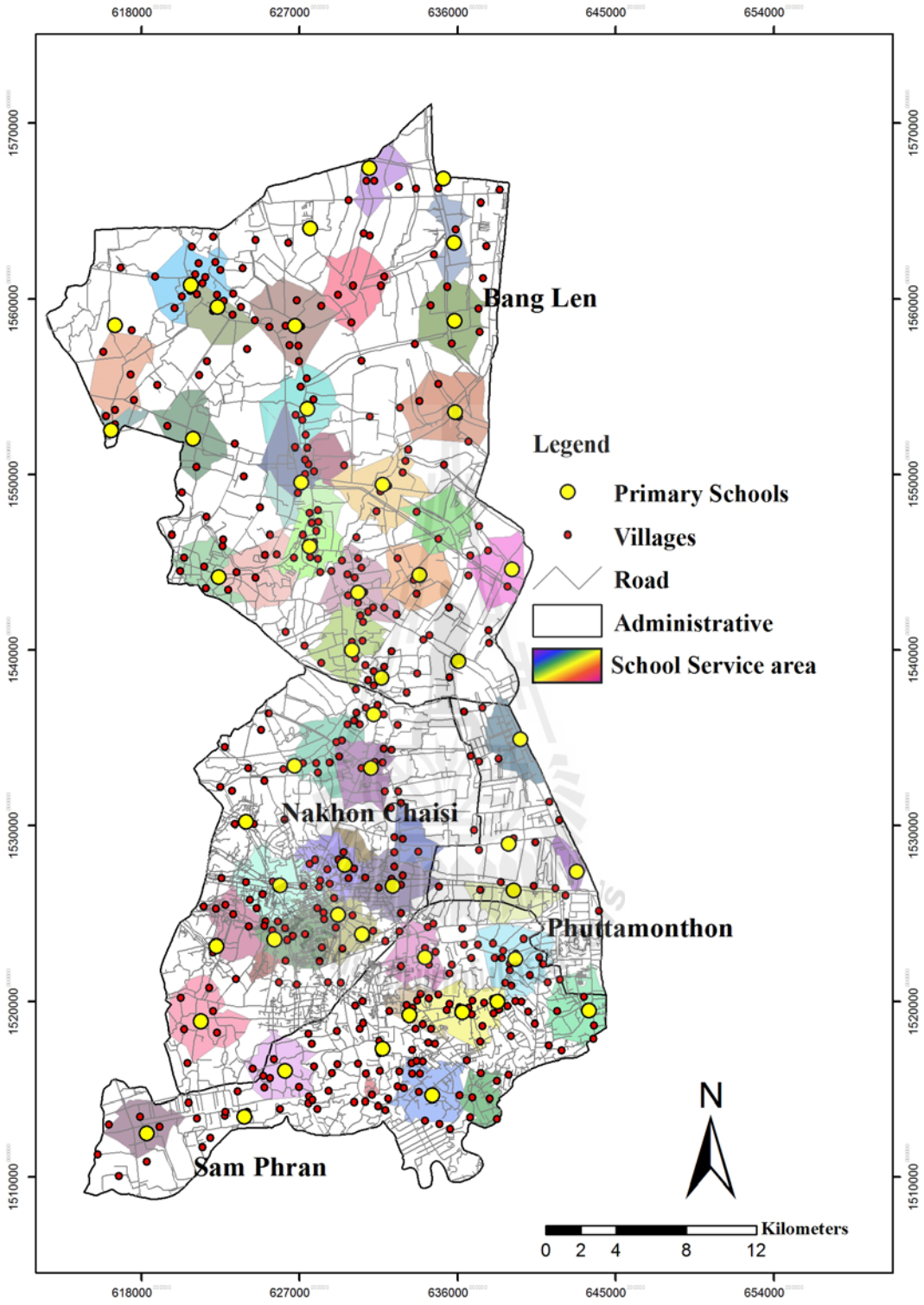


Figure 5.1c Map of school service areas (3 km limit) at P level in 2007 (P-median).

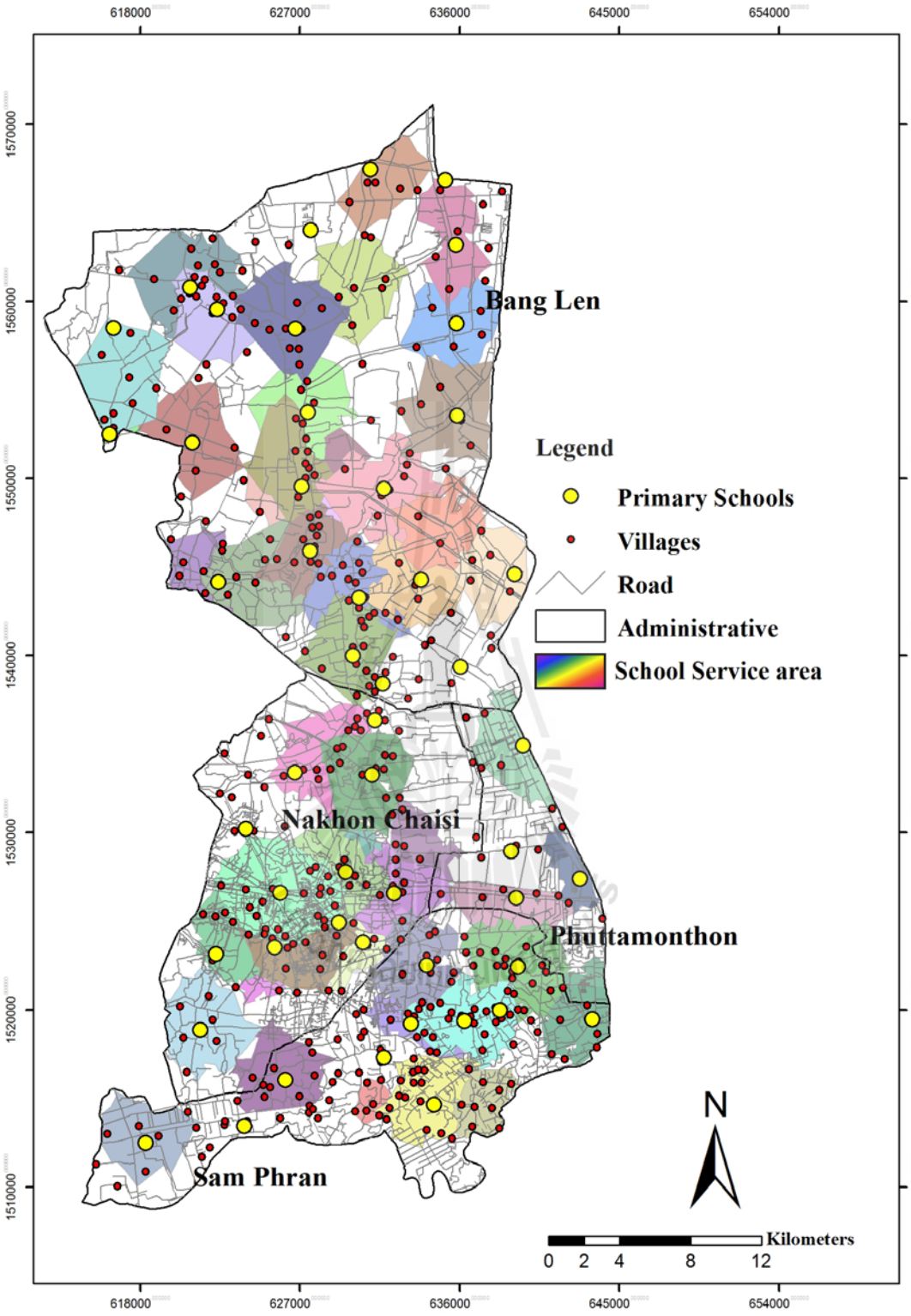


Figure 5.1d Map of school service areas (4 km limit) at P level in 2007 (P-median).

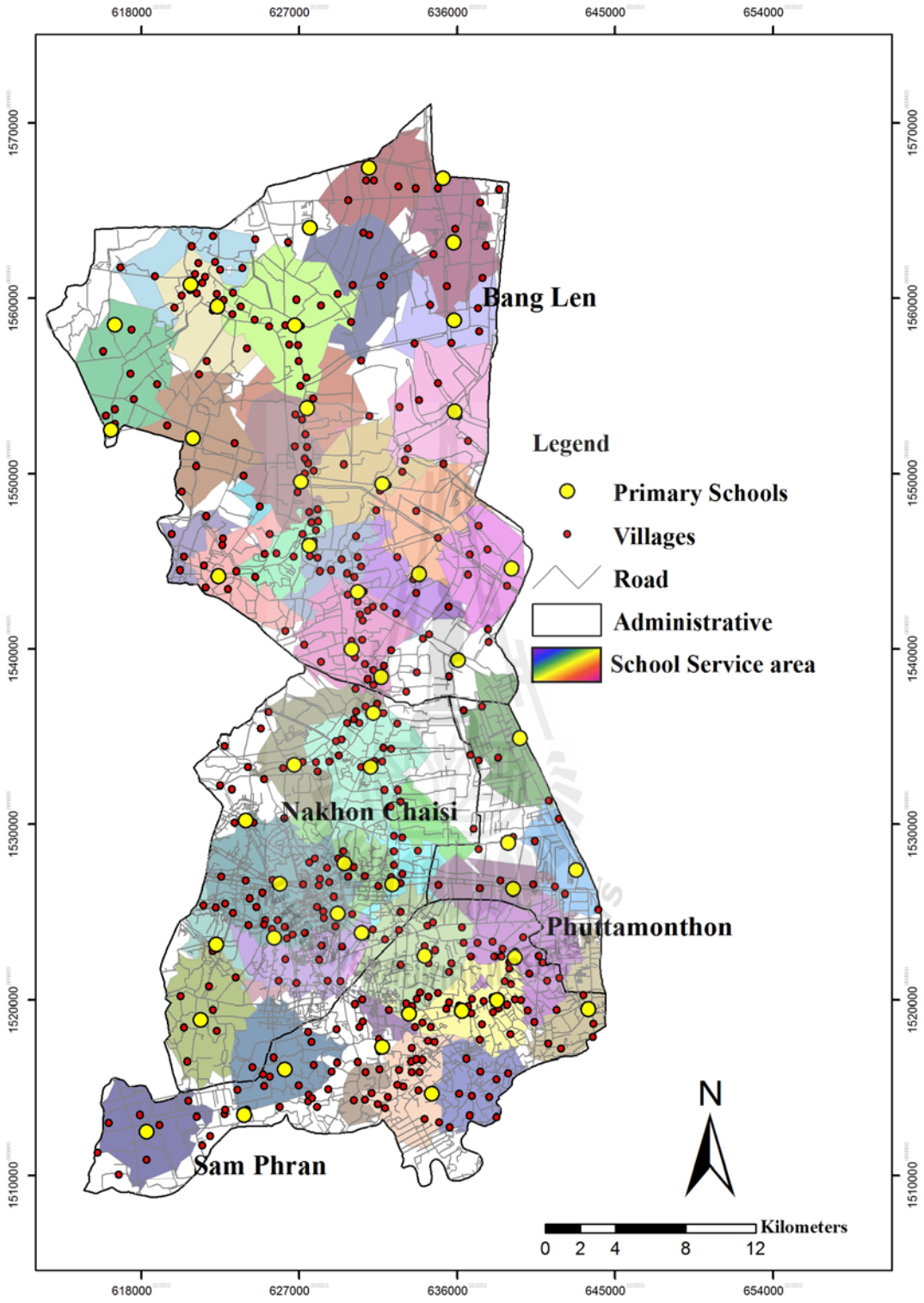


Figure 5.1e Map of school service areas (5 km limit) at P level in 2007 (P-median).

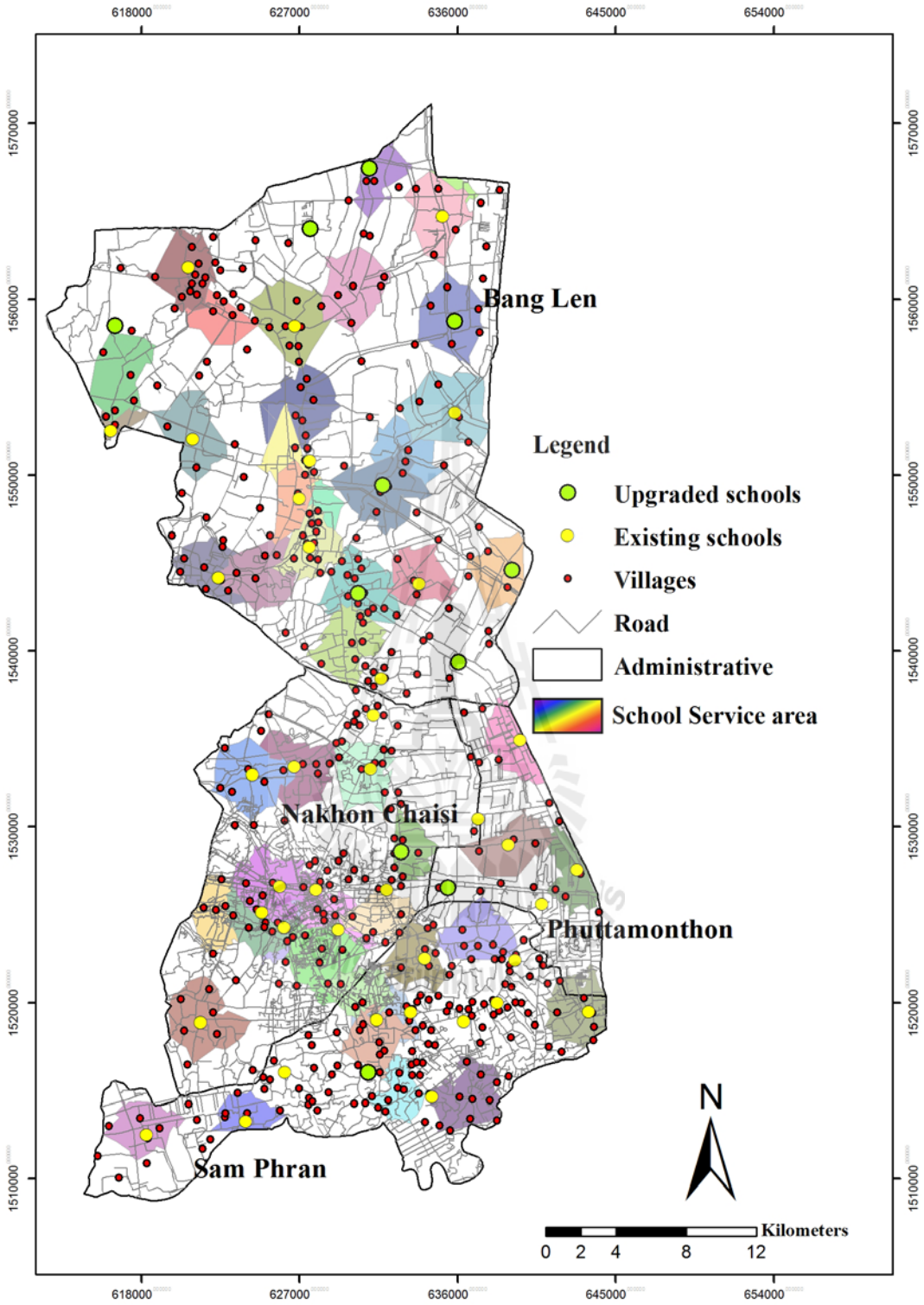


Figure 5.2a Map of school service areas (3 km limit) at LS level in 2007 (P-median).

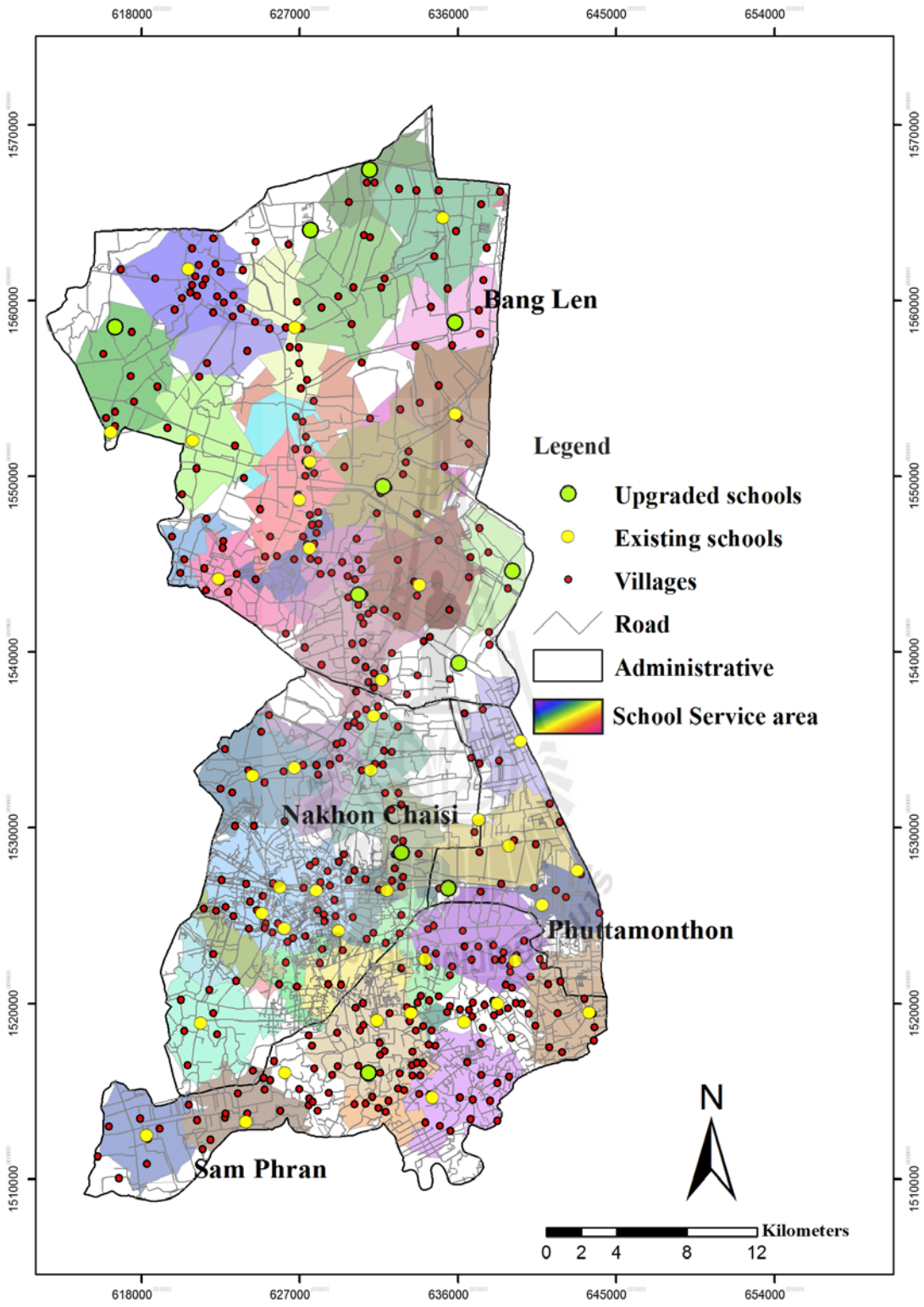


Figure 5.2b Map of school service areas (5 km limit) at LS level in 2007 (P-median).

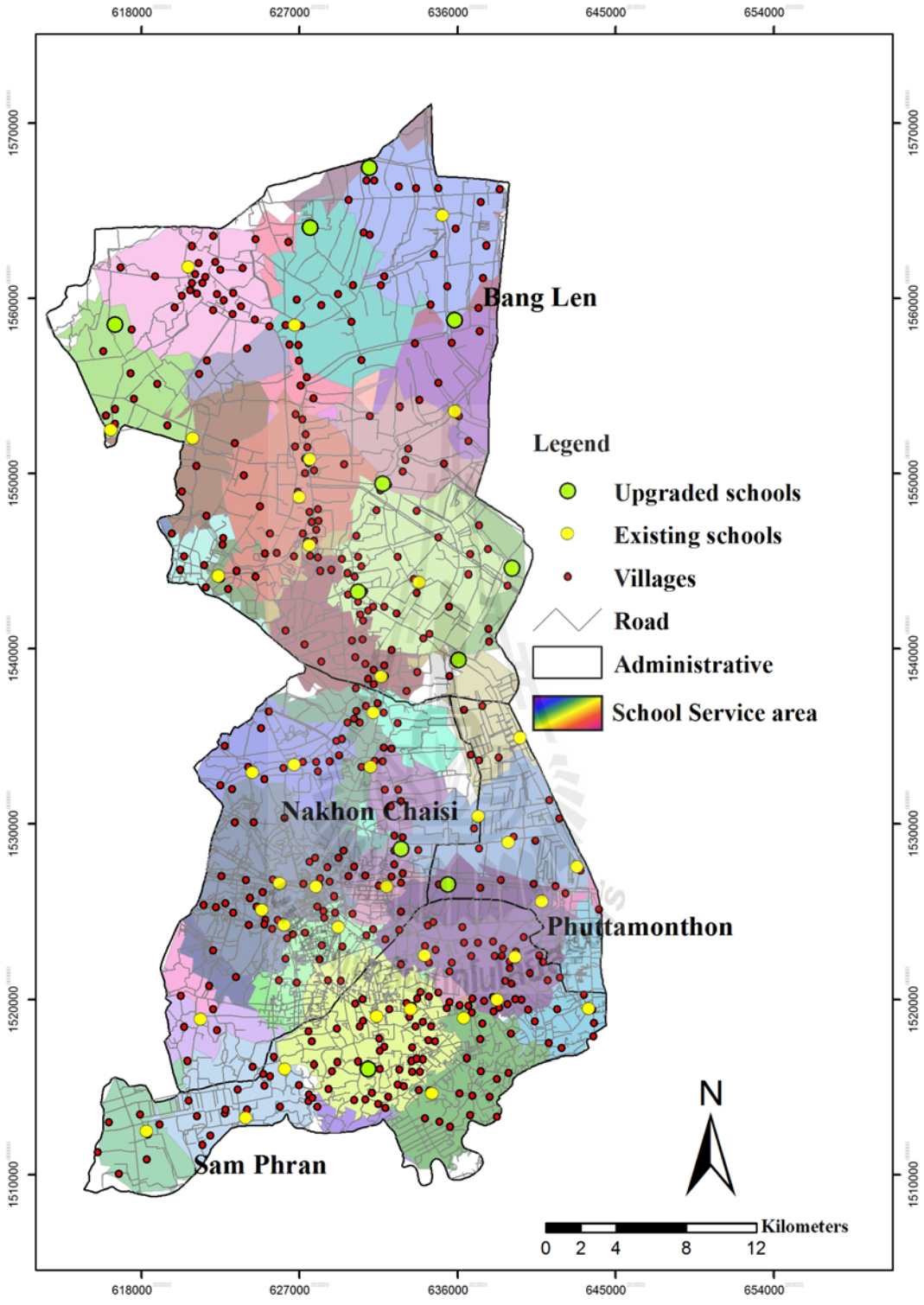


Figure 5.2c Map of school service areas (7 km limit) at LS level in 2007 (P-median).

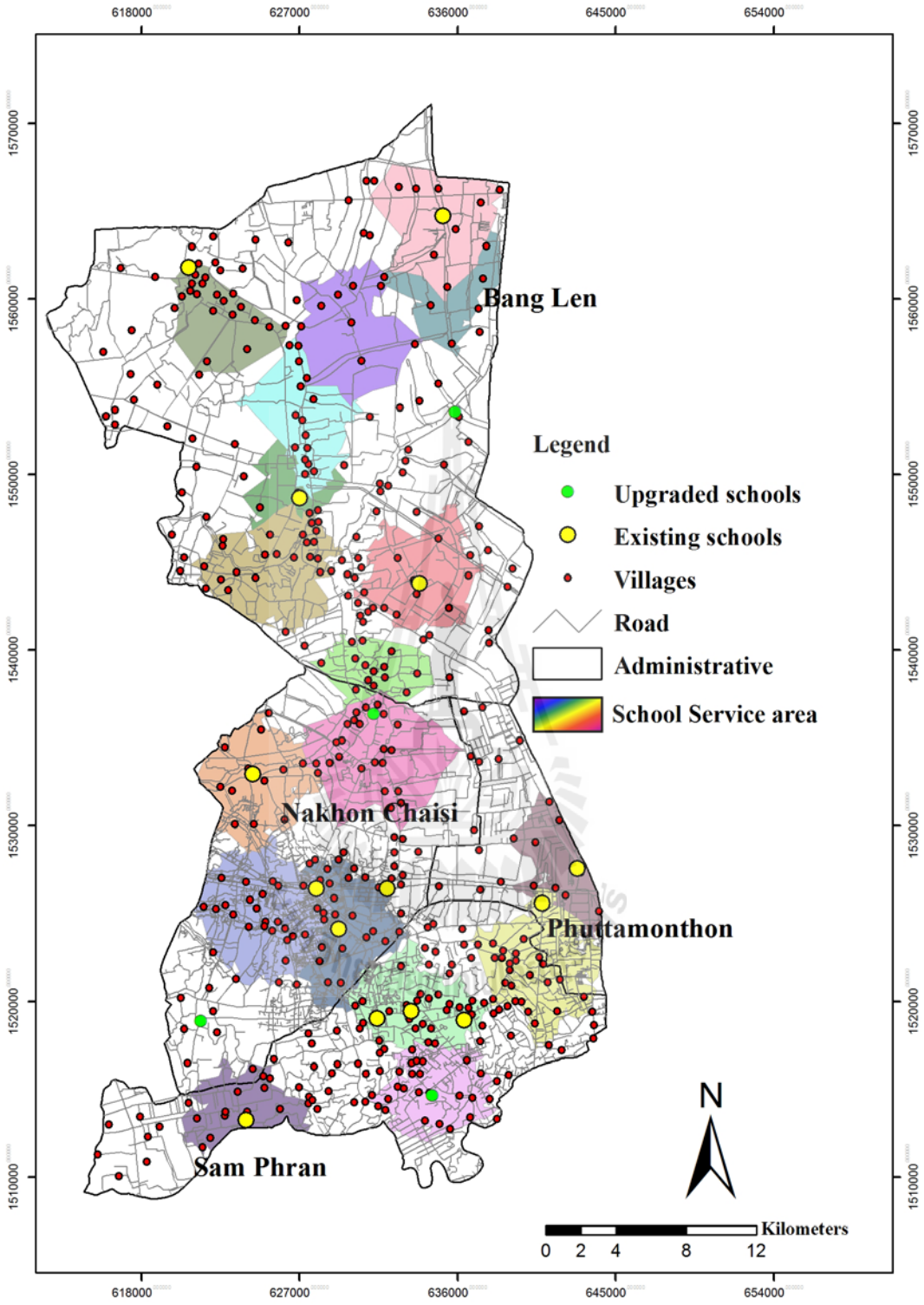


Figure 5.3a Map of school service areas (5 km limit) at US level in 2007 (P-median).

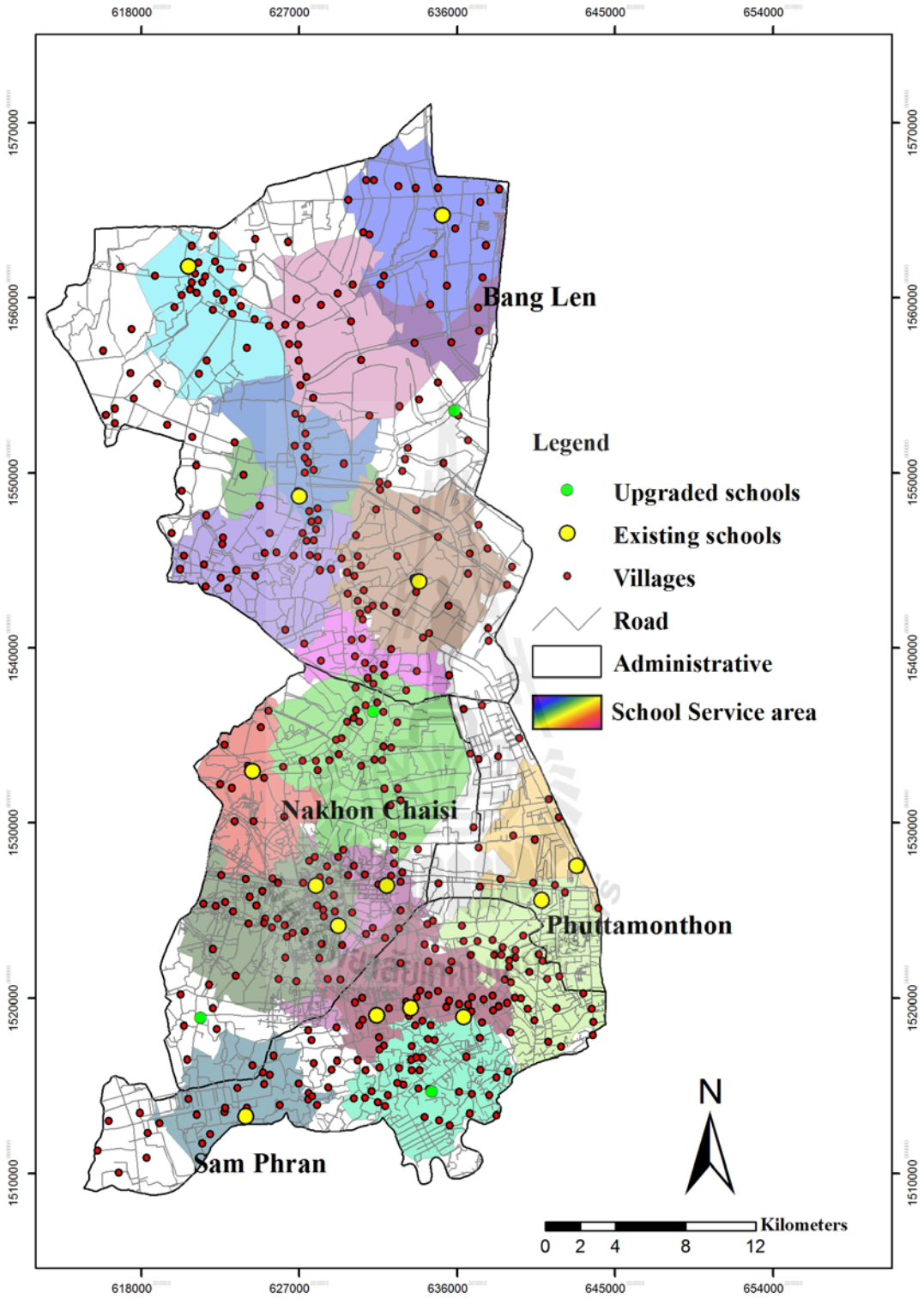


Figure 5.3b Map of school service areas (7 km limit) at US level in 2007 (P-median).

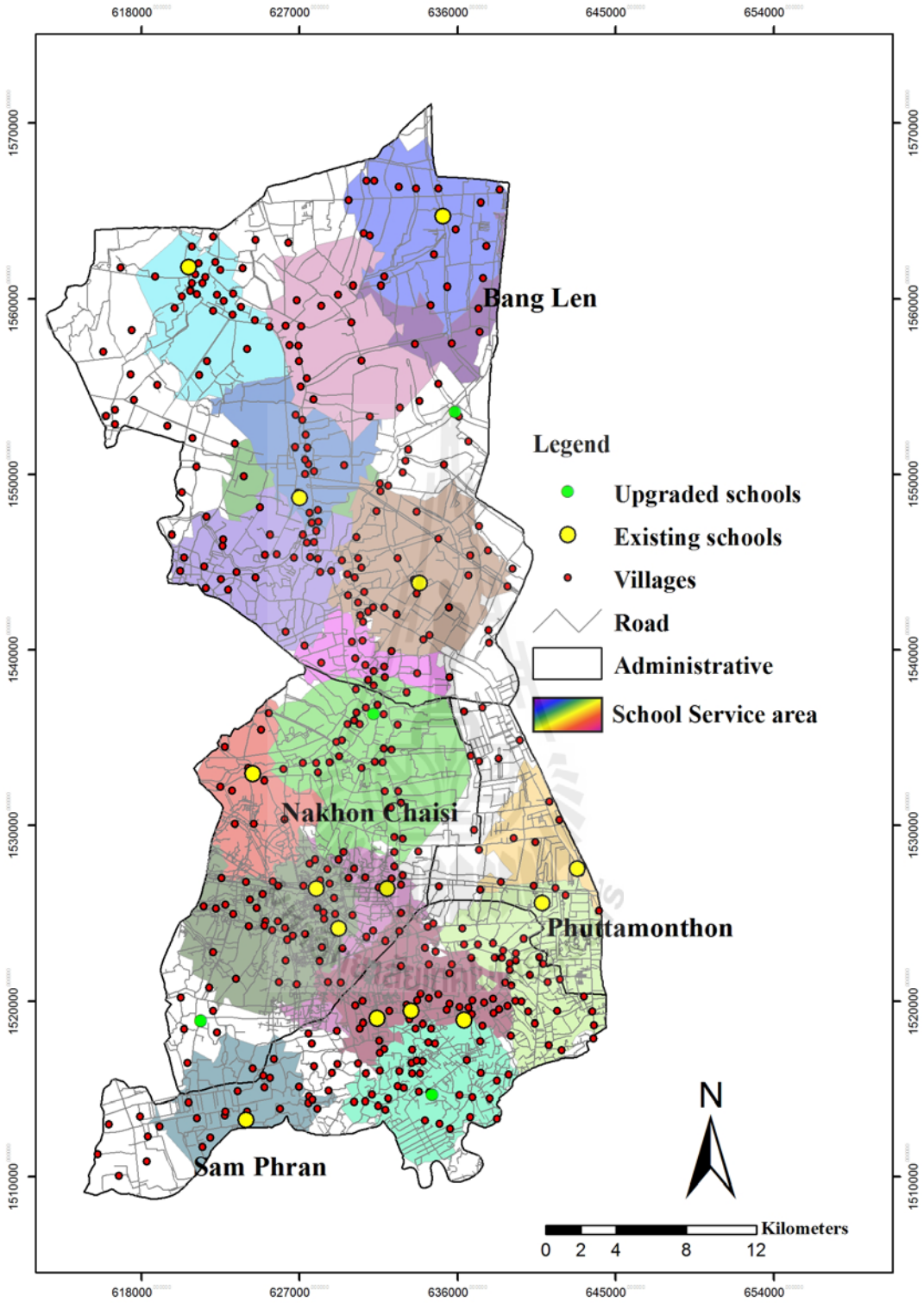


Figure 5.3c Map of school service areas (10 km limit) at US level in 2007 (P-median).

5.1.2 Efficiency assessment in term of the service area

After location and service area maps of the modeled optimum school location sets (as shown in Figures 5.1a-5.1e, 5.2a-5.2c, and 5.3a-5.3c for each school level) were generated, their overall efficiencies were then subsequently assessed in terms of the service area, service loading, and average travel distance under given criteria and results are

Table 5.3 and Figure 5.4 illustrate efficiency of chosen school locations by the p-median model (at all school levels) in term of the service area as depicted in Figures 5.1a-5.1e, 5.2a-5.2c, and 5.3a-5.3c. It is seen that numbers of villages without school service are significantly decreased when distance limits of the service area increase. However, the expansion of given service area could result in notably higher amount of service-overlapping villages, e.g. the overlapped villages for the 3, 5, and 7 km distance limits at the LS level are 15.12%, 36.34%, and 50.56%, respectively. And like in the idealized scenario (in Table 4.8), most overlapped villages (at all levels) are associated with 2-5 schools at once, but if distance limit increases, the overlapping service of more than 5 schools are more visible (e.g. at distance limit ≥5 km). This indicates more redundancy of schools in the overlapped area.

At the distance limits of 3 km (for P and LS levels) and 5 km (for US level) that are preferred by the state's policy, the no-service villages become 38.60%, 44.24%, and 39.73%, while the overlapped villages are 15.80%, 15.82%, and 7.45%, respectively. These numbers indicate that the selected schools locations still cannot provide services to most villages found in the area under these distance limits (about 40% of them are still left out) while the overlapping problem should not be of much concerned. The high value of no-service area at LS level (44.24%) should be of particular concerned.

Table 5.3 School efficiency in term of the service area (P-median).

Level	Distance limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (50)	1	387	87.36	56	12.64	-	-	-	-
	2	286	64.56	136	30.70	21	4.74	-	-
	3	171	38.60	202	45.60	70	15.80	-	-
	4	87	19.64	202	45.60	154	34.76	-	-
	5	38	8.58	161	36.34	241	54.40	3	0.68
LS (50)	3	196	44.24	180	40.63	67	15.12	-	-
	5	68	15.35	214	48.31	161	36.34	-	-
	7	45	10.16	174	39.28	215	48.53	9	2.03
US (18)	5	176	39.73	234	52.82	33	7.45	-	-
	7	68	15.35	214	48.31	161	36.34	-	-
	10	13	2.93	89	20.09	341	76.98	-	-

Note: VIL ≡ number of villages, % ≡ percent of total villages (443).

The no-service problem can be substantially solved if the preferred distance limits are extended, for examples, from 3 km to 5 km at P and LS levels and from 5 km to 7 km at US level. This modification will result in much smaller numbers of no-service villages, which are 8.58% (P level) and 15.35% (LS and US levels). Otherwise, more new schools are required at all educational levels of interest.

At district level (for the distance limits of 3 km at P and LS levels and 5km at US level), Phutthamonthon did worst in term of the no-service area followed by Sam Phran while Bang Len and Nakhon Chai Si did comparatively well. But in term of overlapped area, Phutthamonthon did best followed by Sam Phran (Table 5.4).

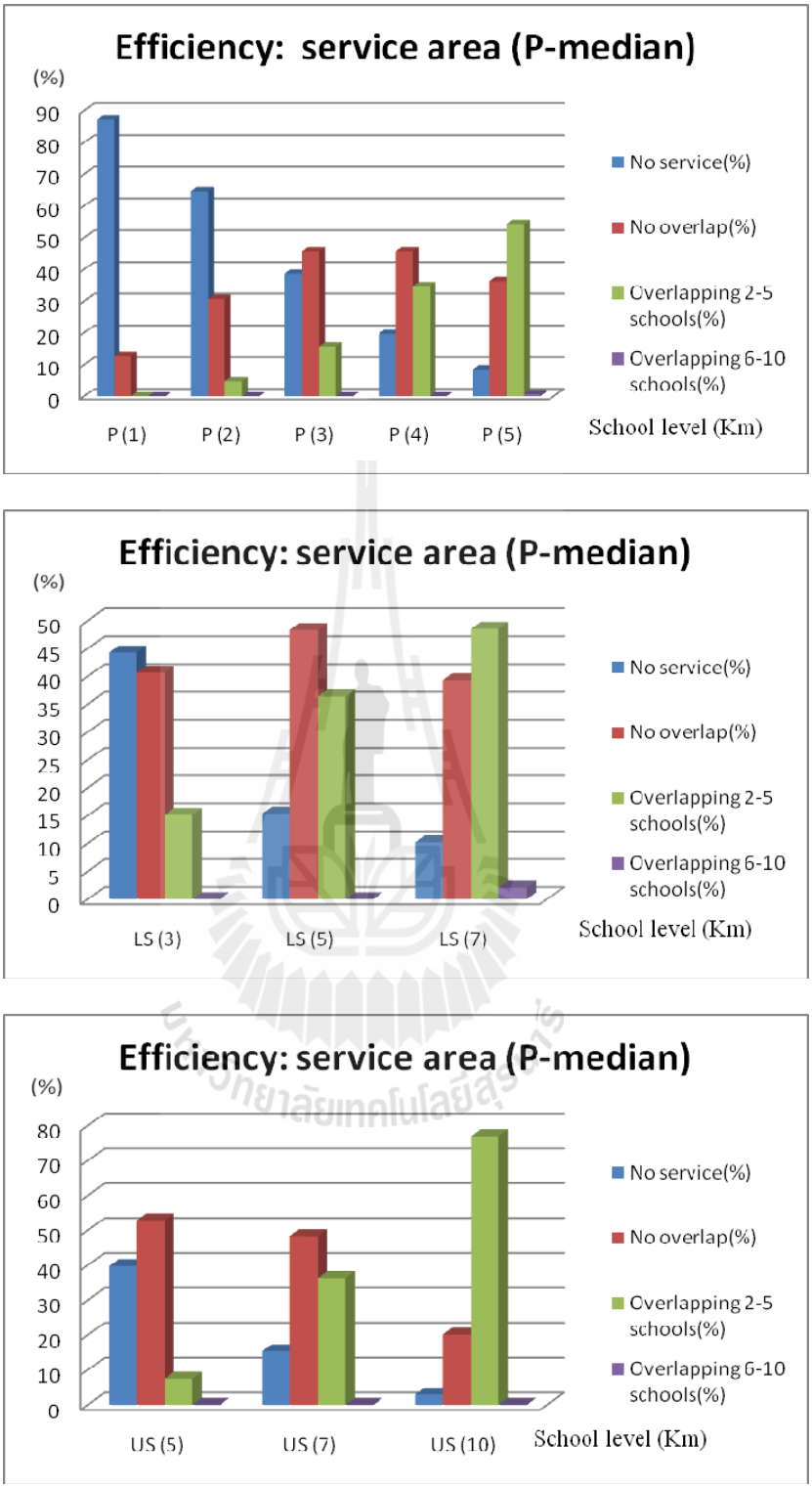


Figure 5.4 School efficiency in term of the service area from Table 5.3 (P-median).

Table 5.4 School efficiency in term of the service area at district level (P-median).

BLN	Limits (km)	No service		No overlap		Overlapping 2-5 schools		Overlapping 6-10 schools	
		VIL	%	VIL	%	VIL	%	VIL	%
P (25)	3	57	31.67	91	50.56	32	17.78	-	-
LS (25)	3	61	33.89	90	50.00	29	16.11	-	-
US (9)	5	83	46.11	83	46.11	14	7.78	-	-
NCS	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (12)	3	36	33.33	38	35.19	34	31.48	-	-
LS (12)	3	41	37.96	36	33.33	31	28.70	-	-
US (4)	5	25	23.15	65	60.19	18	16.67	-	-
PMT	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (3)	3	13	72.22	5	27.78	-	-	-	-
LS (3)	3	11	61.11	7	38.89	-	-	-	-
US (1)	5	9	50.00	9	50.00	-	-	-	-
SPR	**Limits (km)**	**No service**		**No overlap**		**Overlapping 2-5 schools**		**Overlapping 6-10 schools**	
		VIL	**%**	**VIL**	**%**	**VIL**	**%**	**VIL**	**%**
P (10)	3	65	47.45	68	49.64	4	2.92	-	-
LS (10)	3	83	60.58	47	34.31	7	5.11	-	-
US (4)	5	59	43.07	76	56.20	1	0.73	-	-

Note: VIL ≡ number of villages, % ≡ Percent of total villages at each district.

5.1.3 Efficiency assessment in term of the service loading

Efficiencies of the produced school maps (as shown in Figures 5.1-5.3) in term of the service loading were examined and results are reported in Table 5.5 and Figure 5.5. As stated earlier, to determine SL value and calculate potential school scale for a selected school location (on the derived school maps), all current students of the neglected schools are assumed to become members of a selected site that locates

closest to them (weather existing or not-existing school site).

It was evidenced that higher distance limit shall lead to higher number of schools with low SL (at all school levels) as expected. And at distance limits of 3km for P and LS levels and 5km for US level, numbers of school with low SL values (0-50) are about 8.0%, 18.0%, and 5.6%, respectively. This result indicates that the p-median method can generate fairly satisfied result in term of reducing number of schools with relatively low SL values and promoting the moderate/high SL ones. It did comparative well in term of the low SL schools when compared to the idealized method shown in Table 4.12 [at 6.0% (P), 26% (LS) and 0% (US), respectively] and did much better than the present situation reported in Table 4.5 [at 33.86% (P), 33.33% (LS) and 12.5% (US), respectively].

Table 5.5 School efficiency in term of the service loading (P-median).

SL level	P level					LS level			US level		
	1 km	**2 km**	**3 km**	**4 km**	**5 km**	**3 km**	**5 km**	**7 km**	**5 km**	**7 km**	**10 km**
L (critical)	-	-	4	13	21	9	18	23	1	4	7
ML (normal)	1	6	14	16	18	5	6	10	3	4	3
MH (normal)	1	5	12	10	6	6	6	-	4	2	1
H (concerned)	-	6	7	5	2	2	3	-	3	1	1
VH (critical)	29	31	13	6	3	12	1	1	1	1	-
Other	19	2	-	-	-	16	16	16	6	6	6
Total schools	50	50	50	50	50	50	50	50	18	18	18

Note: 1. L ≡ Low, ML ≡ Medium low, MH ≡ Medium high, H ≡ High, VH ≡ Very high.

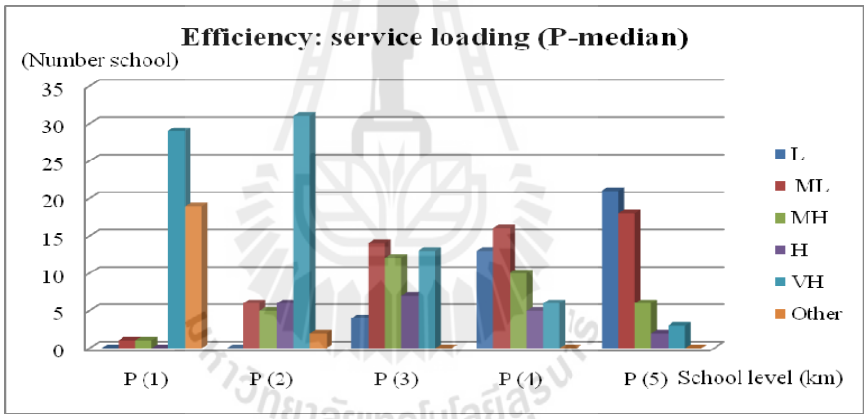
2. Other ≡ No valid SL identified as ACT or POT = 0.

Table 5.6 Average SL values for different school scales (P-median).

School scale	P level					LS level			US level		
	1 km	2 km	3 km	4 km	5 km	3 km	5 km	7 km	5 km	7 km	10 km
S	1035.7	254.8	38.5	22.8	22.8	54.6	31.3	19.9	26.5	13.0	7.4
M	1028.9	415.2	133.8	87.0	59.6	150.2	63.2	31.7	50.6	34.7	19.5
L	1276.1	356.6	325.4	148.0	103.9	778.5	116.9	60.4	87.7	61.3	30.4
VL	1062.0	287.1	197.3	148.4	96.4	984.4	162.1	120.5	-	-	-

Note: 1. Cases that have no potential student in the specified service area (POT = 0) are not included.

2. School scale: S ≡ Small (1-120 students), M ≡ Medium (121-600 students),
L ≡ Large (601-1500 students), VL ≡ Very large (>1500 students).



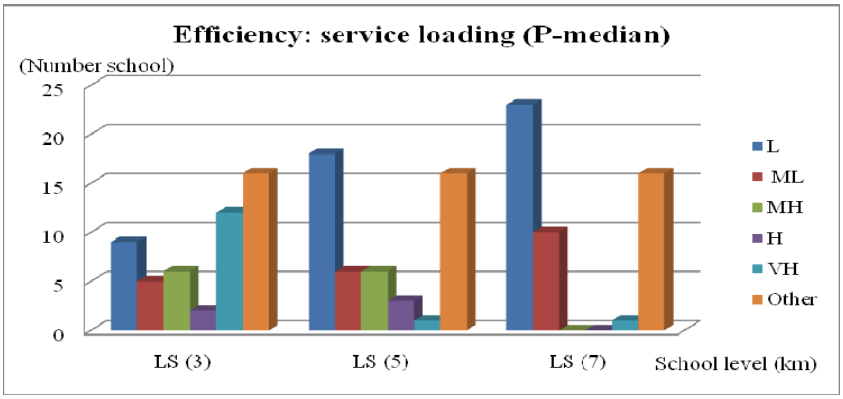


Figure 5.5 School efficiency in term of the service loading from Table 5.5 (P-median).

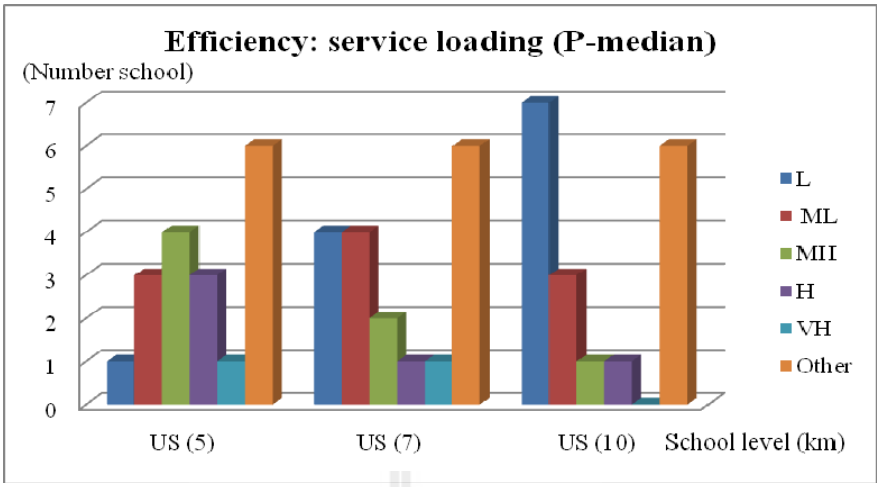


Figure 5.5 School efficiency in term of the service loading from Table 5.5 (P-median) (Continued).

Table 5.7 School efficiency in term of service loading at district level (P-median).

BLN	Limits (km)	L		ML		MH		H/VH		Other	
		SCH	%	SCH	%	SCH	%	SCH	%	SCH	%
P (25)	3	3	12.00	6	24.00	6	24.00	10	40	-	-
LS (25)	3	2	8.00	2	8.00	4	16.00	5	20.00	12	48.00
US (9)	5	-	-	-	-	1	11.11	3	33.33	5	55.56
NCS	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (12)	3	1	8.33	5	41.67	5	41.67	1	8.33	-	-
LS (12)	3	4	33.33	1	8.33	2	16.67	2	16.67	3	25.00
US (4)	5	-	-	1	25.00	-	-	3	75.00	-	-
PMT	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (3)	3	-	-	-	-	-	-	3	100.00	-	-
LS (3)	3	1	12.50	-	-	-	-	2	66.67	-	-
US (1)	5	-	-	-	-	-	-	1	100.00	-	-
SPR	**Limits (km)**	**L**		**ML**		**MH**		**H/VH**		**Other**	
		SCH	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**	**SCH**	**%**
P (10)	3	-	-	3	30.00	1	10.00	6	60.00	-	-
LS (10)	3	2	20.00	2	20.00	-	-	5	50.00	1	10.00
US (4)	5	-	-	-	-	-	-	3	75.00	1	25.00

Note: SCH ≡ number of schools, % ≡ percent of total schools at each district (at a specific level).

Table 5.8 School efficiency in term of the average travel distance (comparison).

Distance (km)	P level			LS level			US level			
	PR-1 (127)	**IDL (50)**	**PMD (50)**	**PR-1 (39)**	**IDL (50)**	**PMD (50)**	**PR-1 (16)**	**IDL (18)**	**PMD (18)**	**GPMD (18)**
Maximum	5.02	7.78	8.63	8.33	7.58	7.76	13.16	12.83	12.83	27.98
Average	1.62	2.46	1.97	2.66	2.40	2.01	4.80	4.19	2.91	4.22

Note: 1. PR-1 ≡ Present situation; IDL ≡ Idealized scenario; PMD ≡ P-median scenario; GPMD ≡ Gravity P-median scenario**.**

5.1.4 Efficiency assessment in term of the travel distance to school

Results of the analysis in Table 5.8 indicates that average travel distances of the students (based on the p-median method) are 1.97 km (P level), 2.01 km (LS level), and 2.91 km (US level). The average value of 1.97 km (with maximum of 8.63 km) at P level may be rather higher than that of the existing situation (average 1.62 km with maximum 5.02 km) due to significant decrease in number of the preferred schools (from 127 to 50). However, these values are still reasonably acceptable nowadays for the cycling or motor-vehicle modes of travelling to school of students. However, in the walking mode of travel students may be able to find some shorter routes (not on the major road network) that can take them to their schools at shorter distances than the found average value of about 2 km mentioned here. This makes the walking mode of travel still being applicable in reality. And obtained value of 1.97 km provided by p-median method is significantly lower than that of the idealized method (at 2.46 km). This means solution of the p-median model should be more advantage to the students in term of the traveling distance alone than that one being derived from the idealized technique.

The average values of 2.01 km (with maximum of 7.76 km) at LS level, and 2.91 km (with maximum of 12.83 km) at US level, are significantly lower than

those obtained from the present situation (average 2.66 km/maximum 8.33 km at LS level and average 4.80 km/maximum 13.16 km at US level). These should be due to the initial conditions of the model that try to determine a specific set of school locations that provide minimum average travel distance to students, though numbers of schools preferred at these levels are rather comparable (39 to 50 at LS level and 16 to 18 at US level) and most existing schools at both levels were still retained by p-median method. This makes school location maps (at LS and US levels) of the present and p-median scenarios do not appear much different from each other but the found average travel distances are noticeably different, especially at the US level (see Figures 4.7a-4.7c, 5.2a-5.2c, and 4.8a-4.8c, and 5.3a-5.3c for a visual comparison at the LS and US levels, respectively). The p-median method also performed much better than the idealized method in term of the travel distance alone as seen in Table 5.8.

5.1.5 School mapping and efficiency assessment in years 2015 and 2020

To evaluate effect of the local population variation on the characteristics of future optimum school maps initiated by the p-median model, the school maps for years 2015 and 2020 were synthesized as shown in Figures 5.7a-5.7e, 5.8a-5.8c, and 5.9a-a.9c using predicted population data of those years. These maps were produced based on the typical process of the p-median method described in Section 3.2.4. Numbers of the potential and ideal school sites (at each relevant school level) for each district are as described in Table 3.4 and the potential sites in both years were assumed to be the same as those for year 2007.

Table 5.9 School efficiency comparison for years 2007, 2015, and 2020 (P-median).

School level	No-service (%) (village-based)			Overlapped (%) (village-based)			Travel distance (km)		
	2007	2015	2020	2007	2015	2020	2007	2015	2020
P (1km)	87.36	87.36	87.36	-	-	-			
P (2km)	64.56	64.56	64.56	4.74	4.51	4.51			
P (3km)	38.60	39.50	39.50	15.8	15.58	15.58	1.97	2.06	1.97
P (4km)	19.64	20.54	20.54	34.76	33.41	33.41			
P (5km)	8.58	10.16	10.16	55.08	54.18	54.18			
LS (3km)	44.24	41.76	41.76	15.12	13.54	13.54			
LS (5km)	15.35	9.26	9.26	36.34	53.72	53.72	2.01	2.10	2.21
LS (7km)	10.16	0.23	0.23	50.56	84.43	84.43			
US (5km)	39.73	36.57	39.73	7.45	10.84	7.45			
US (7km)	15.35	16.70	15.35	36.34	42.21	36.34	2.91	2.65	2.56
US (10km)	2.93	6.09	2.93	76.98	76.75	76.98			

It was found that the generated optimum school maps for years 2015 and 2020 (at each school level) do not look much different from each other and some of the obtained maps have exactly the same set of preferred school locations (as seen in Figures 5.7a-5.7e, 5.8a-5.8c, and 5.9a-a.9c). The constructed 2015 and 2020 maps also look rather similar to those invented for year 2007 (Figures 5.1a-5.1e, 5.2a-5.2c, and 5.3a-5.3c). These similarities are likely to come up from the same set of used potential sites and numbers of population (at village level) that do not differ much during 2007-2020 (except in some areas). Due to the similarity of optimum school maps created for all these years (2007, 2015, and 2020), their general efficiencies in term of the service area (no-service and overlapped service) and average travel distance are also not different much from each other as shown in Table 5.9 and Figure 5.6.

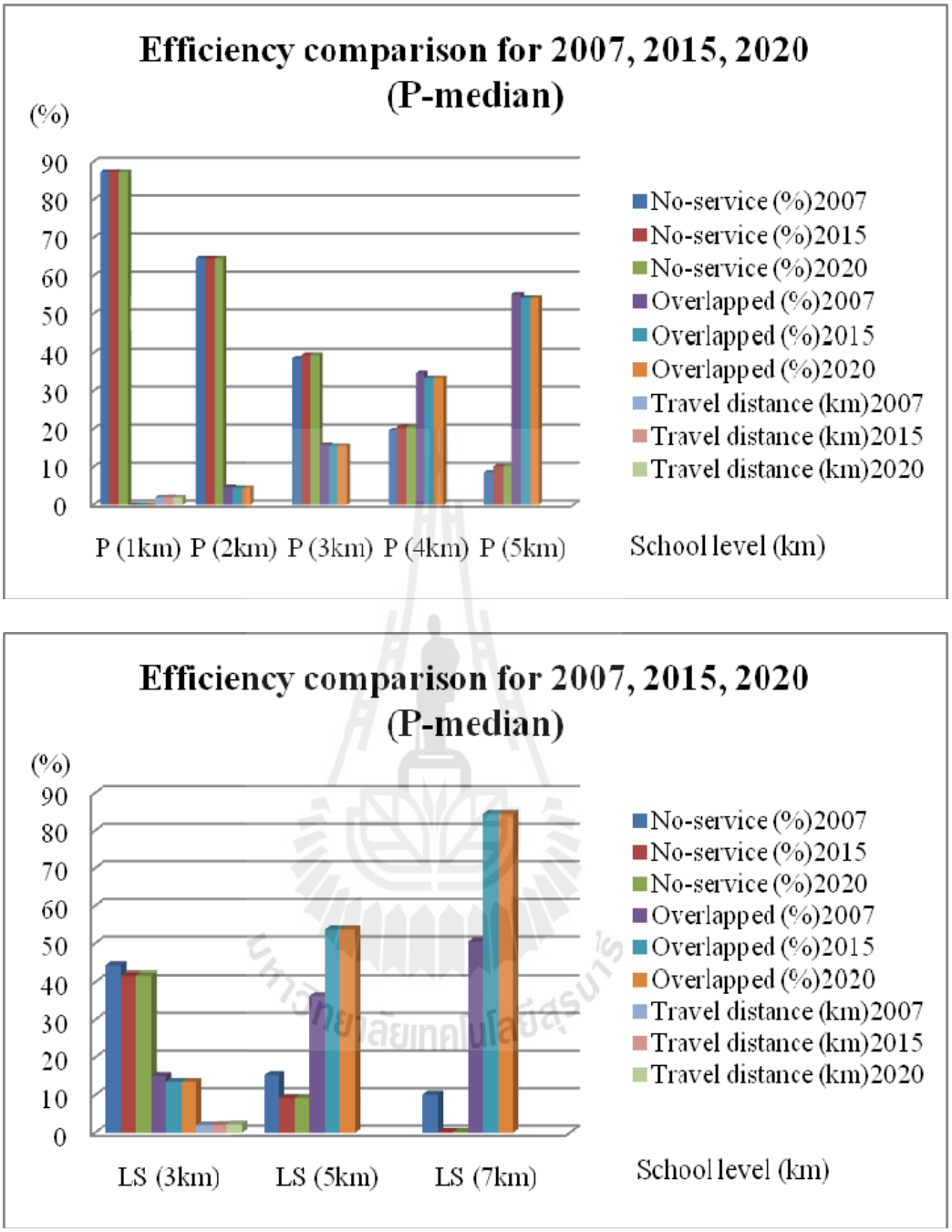


Figure 5.6 School efficiency comparisons for years 2007, 2015, and 2020 (P-median) (Table 5.9).

Table 5.10a Lowest values of travel distances given by the p-median model (2015).

Order (P)	Bang Len		Nakhon Chai Si		Phutthamonthon		Sam Phran	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	16852.16	2.43	19296.10	2.28	7003.46	2.03	41621.00	1.53
2	16965.37	2.45	19411.23	2.29	7103.77	2.06	41697.38	1.53
3	17069.07	2.46	19481.55	2.30	7718.29	2.24	42455.89	1.56
4	17131.95	2.47	19588.23	2.31	8138.90	2.36	42532.27	1.56
5	17181.58	2.48	19600.90	2.31	8916.59	2.58	42562.82	1.56
Order (LS)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	9822.77	2.47	10652.97	2.30	4469.63	2.36	22304.86	1.49
2	9892.901	2.49	10672.97	2.30	4540.74	2.40	22642.01	1.51
3	9960.577	2.51	10716.70	2.31	5109.23	2.70	22722.78	1.52
4	9973.862	2.51	10759.71	2.32	5201.96	2.75	22737.93	1.52
5	10002.53	2.52	10768.81	2.32	5553.19	2.94	22813.21	1.53
Order (US)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	12534.31	2.83	13162.29	2.78	12409.74	6.99	33616.92	2.40
2	12549.17	2.83	13362.03	2.82	12988.41	7.31	34215.09	2.44
3	12583.28	2.84	13374.08	2.82	13058.70	7.35	34946.71	2.50
4	12598.14	2.84	13378.46	2.82	-	-	35353.24	2.53
5	12601.28	2.84	13395.23	2.83	-	-	35923.56	2.57

Note: Total ≡Total travel distance (in km), Average≡ Average travel distance per student (in km).

Table 5.10b Lowest values of travel distances given by the p-median model (2020).

Order (P)	Bang Len		Nakhon Chai Si		Phutthamonthon		Sam Phran	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	16693.61	2.38	19852.99	2.27	8058.58	2.03	53191.42	1.50
2	16794.58	2.40	19963.7	2.28	8191.45	2.06	53491.38	1.51
3	16892.57	2.41	20019.56	2.29	8878.99	2.23	54060.74	1.53
4	16942.19	2.42	20160.02	2.31	9380.78	2.36	54238.29	1.53
5	17005.41	2.43	20172.73	2.31	10290.96	2.59	54360.70	1.54
Order (LS)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	10070.69	2.51	10959.99	2.29	5145.32	2.36	29159.54	1.50
2	10158.88	2.53	10985.35	2.29	5226.71	2.40	29717.46	1.53
3	10205.26	2.54	11004.97	2.30	5880.52	2.70	29809.50	1.53
4	10246.82	2.55	11023.92	2.30	5994.53	2.75	29833.14	1.54
5	10292.23	2.57	11037.81	2.31	6386.09	2.93	29837.55	1.54
Order (US)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	11800.71	2.76	13565.78	2.77	14352.50	7.01	40405.27	2.24
2	11849.68	2.78	13746.85	2.80	14991.98	7.32	42218.38	2.34
3	11896.59	2.79	13769.69	2.81	15104.40	7.38	42300.29	2.35
4	11902.25	2.79	13775.89	2.81	-	-	42787.13	2.38
5	11935.90	2.80	13798.73	2.82	-	-	43090.95	2.39

Note: Total ≡Total travel distance (in km), Average≡ Average travel distance per student (in km).

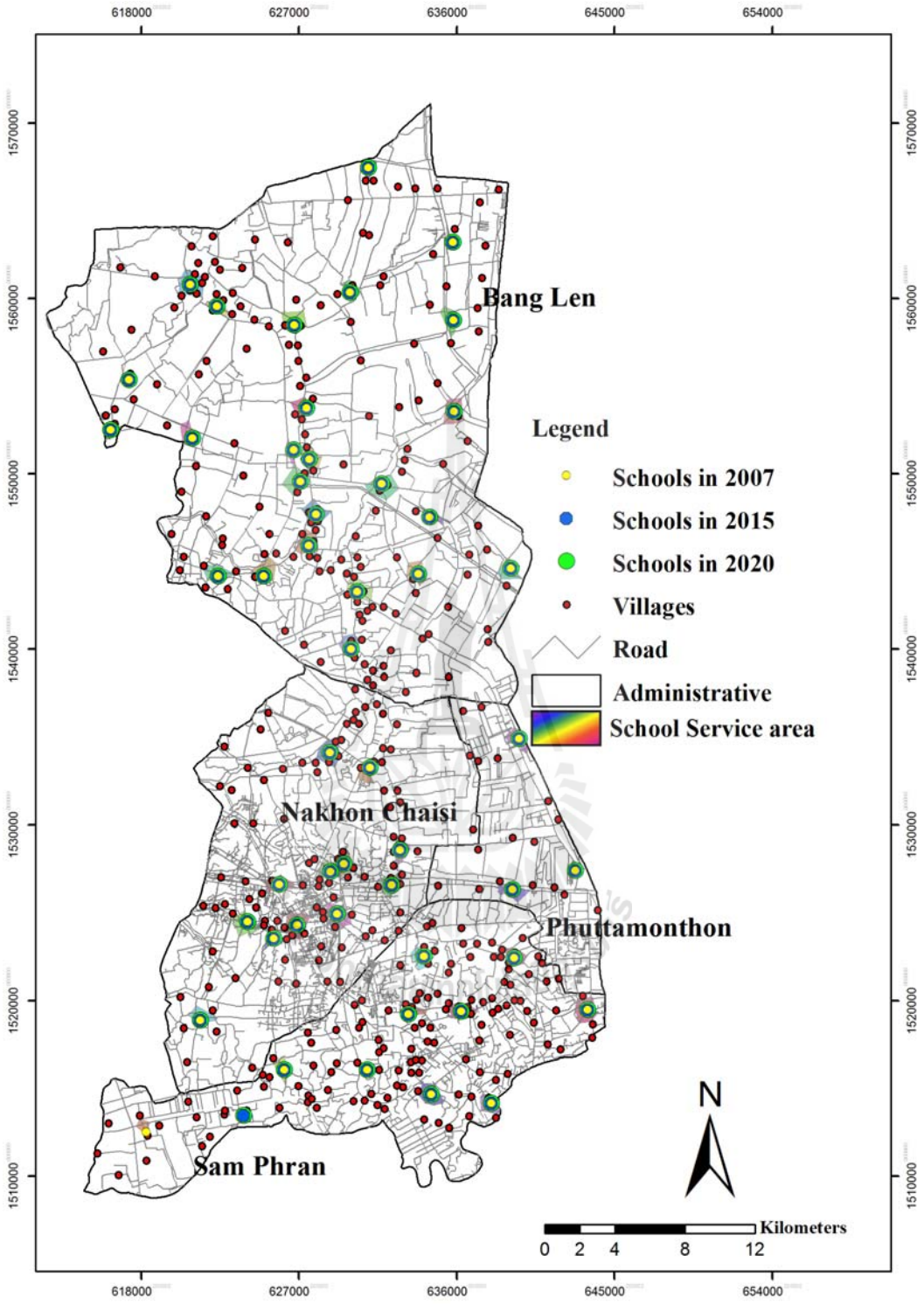


Figure 5.7a Map of school service areas (1 km limit) at P level in 2015/2020 (P-median).

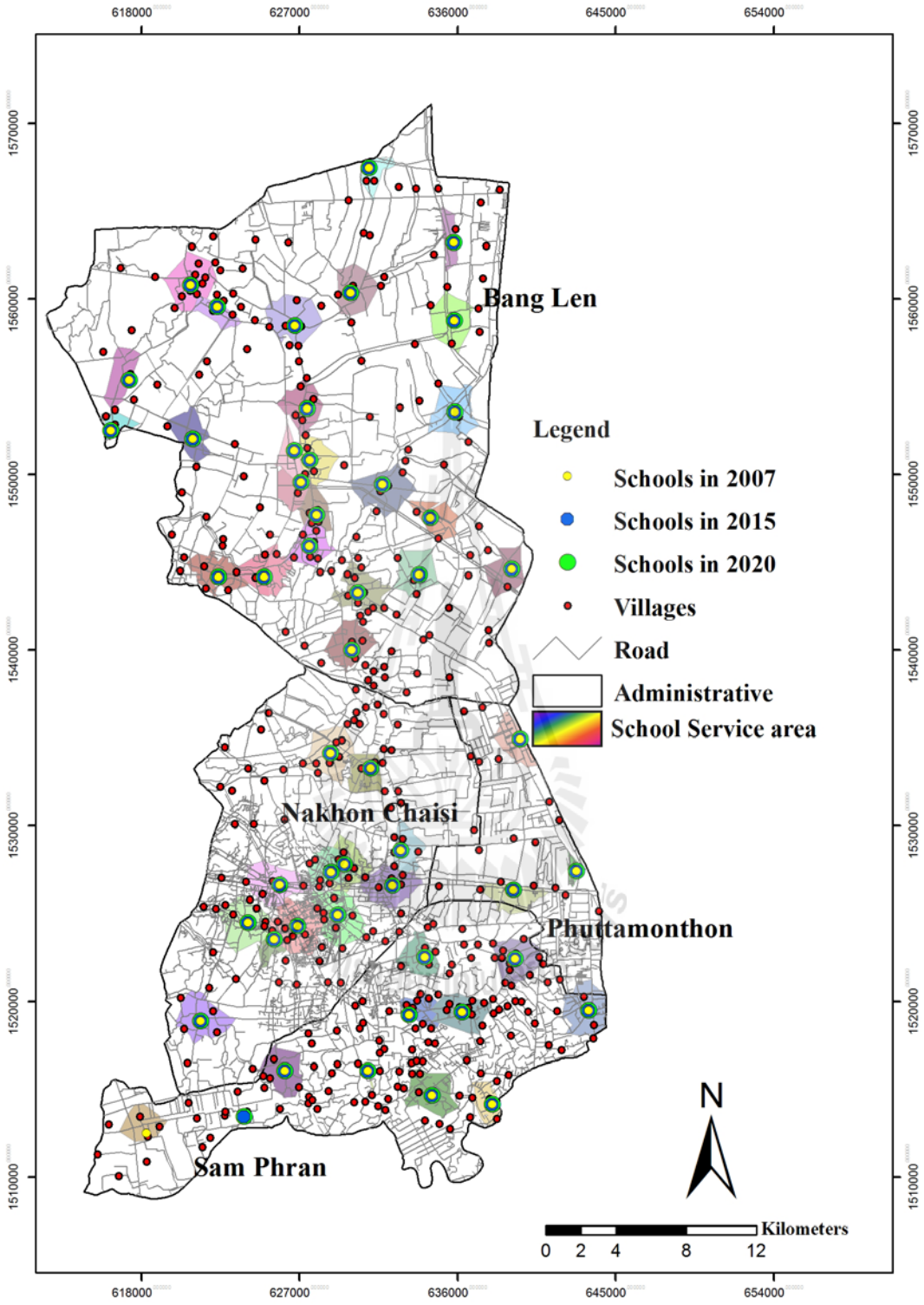


Figure 5.7b Map of school service areas (2 km limit) at P level in 2015/2020 (P-median).

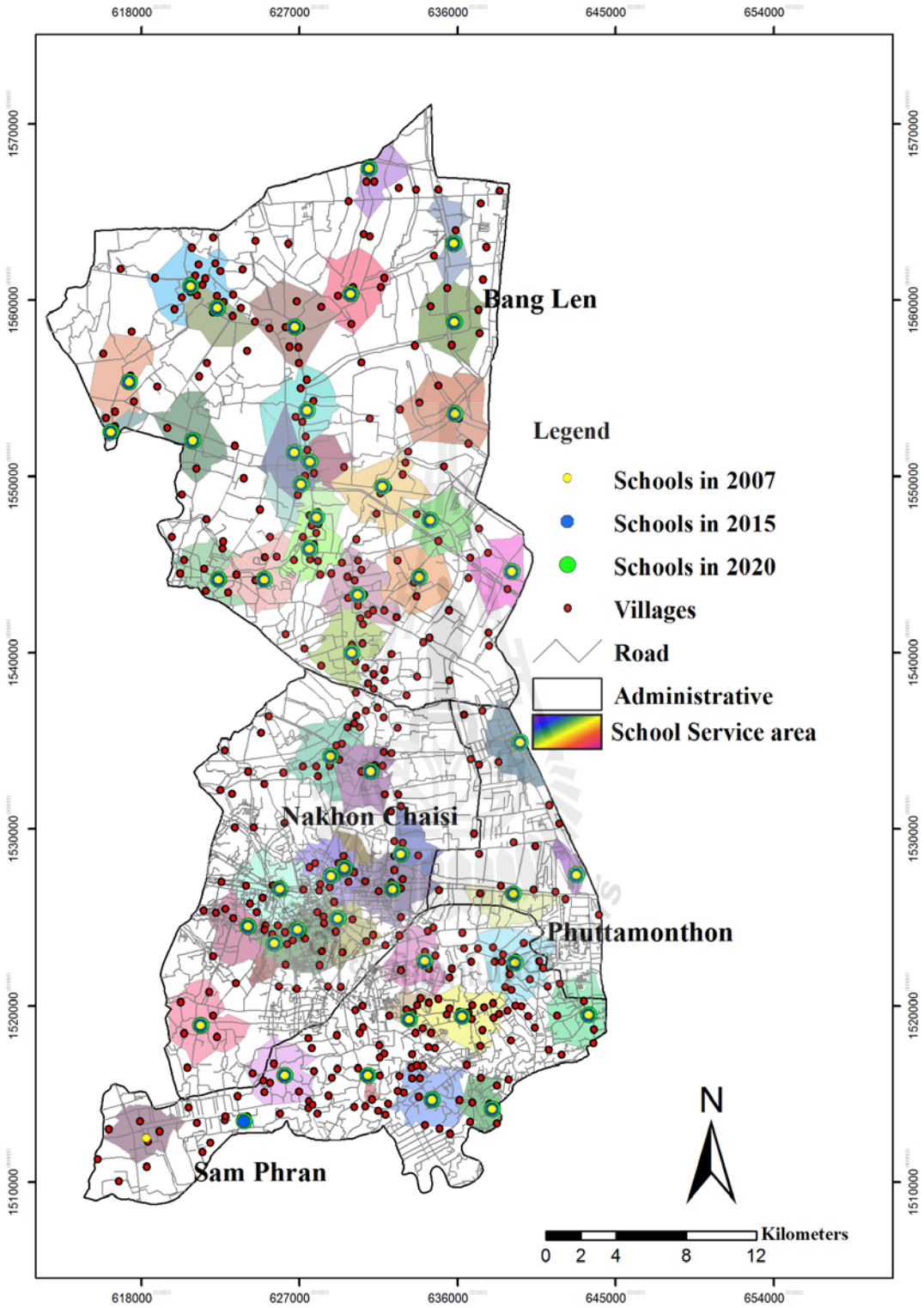


Figure 5.7c Map of school service areas (3 km limit) at P level in 2015/2020 (P-median).

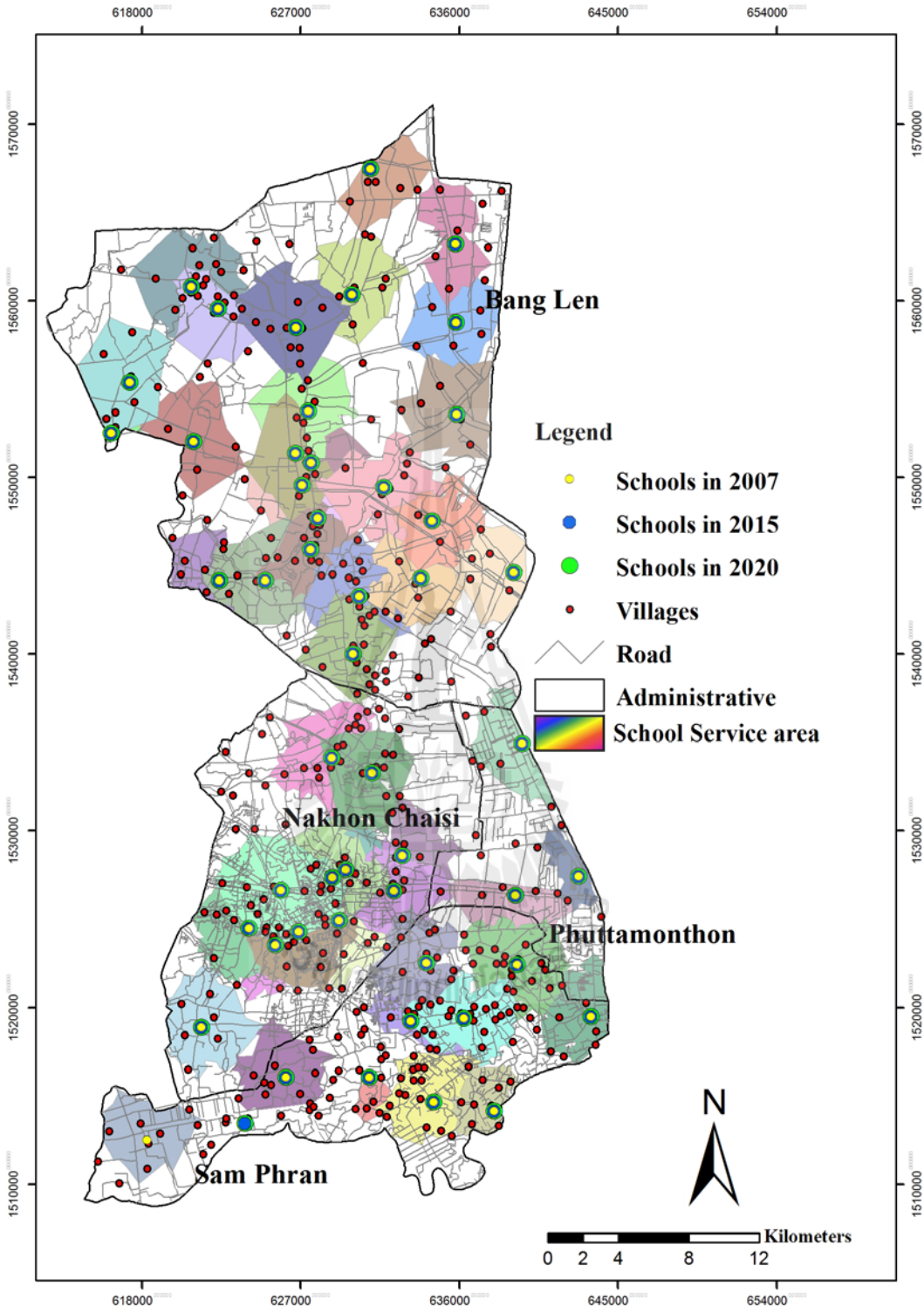


Figure 5.7d Map of school service areas (4 km limit) at P level in 2015/2020 (P-median).

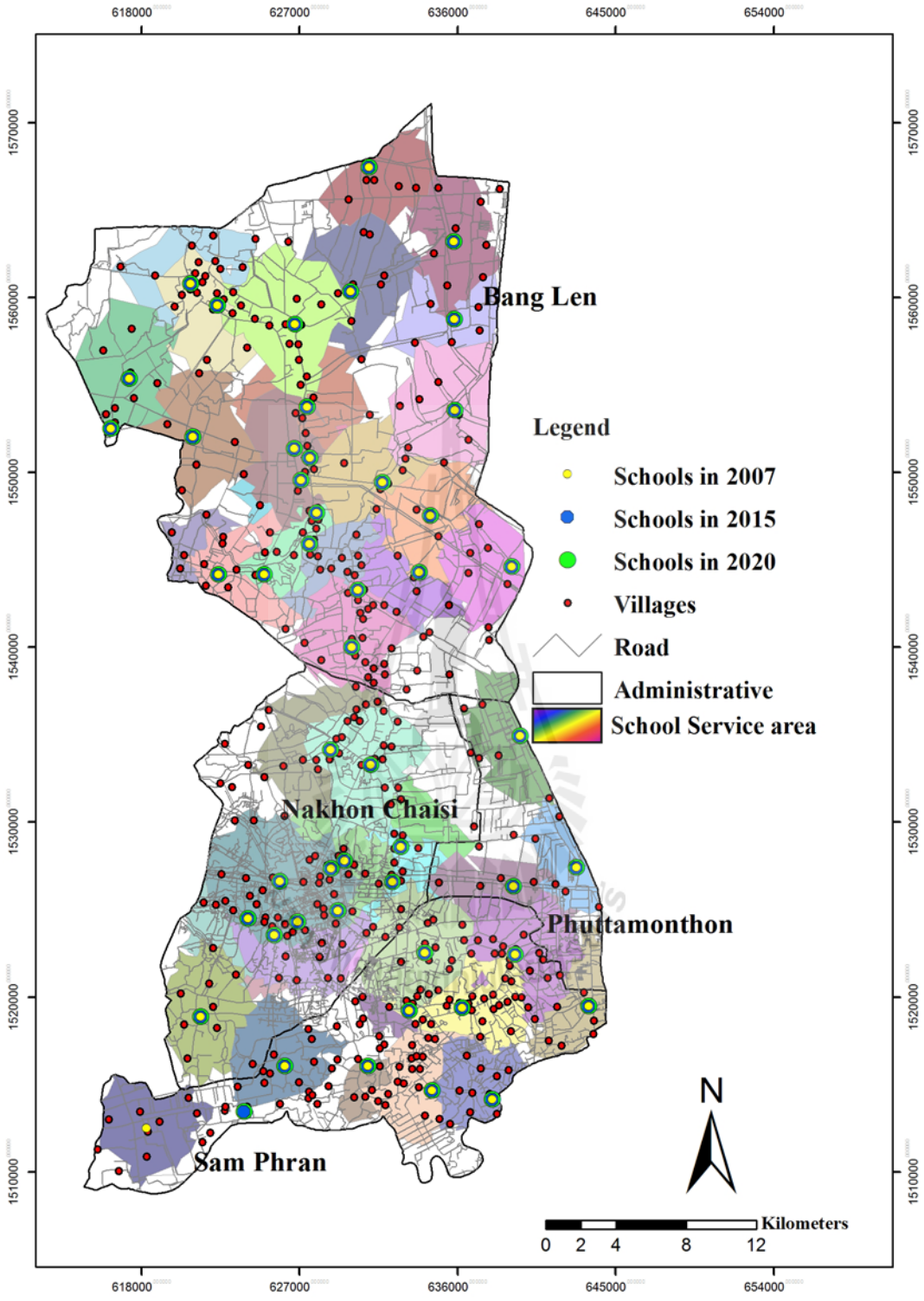


Figure 5.7e Map of school service areas (5 km limit) at P level in 2015/2020 (P-median).

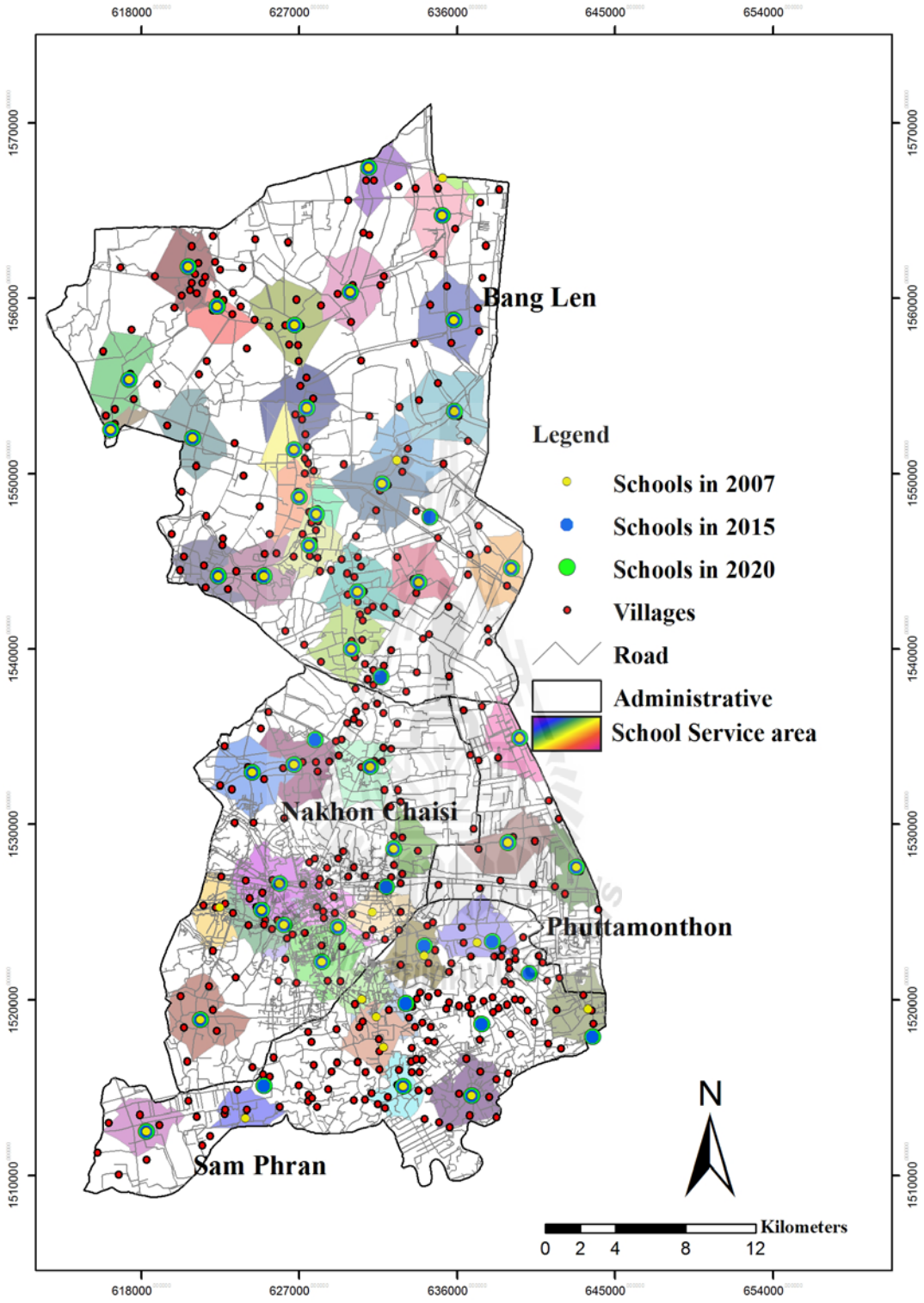


Figure 5.8a Map of school service area (3 km limit) at LS level in 2015/2020 (P-median).

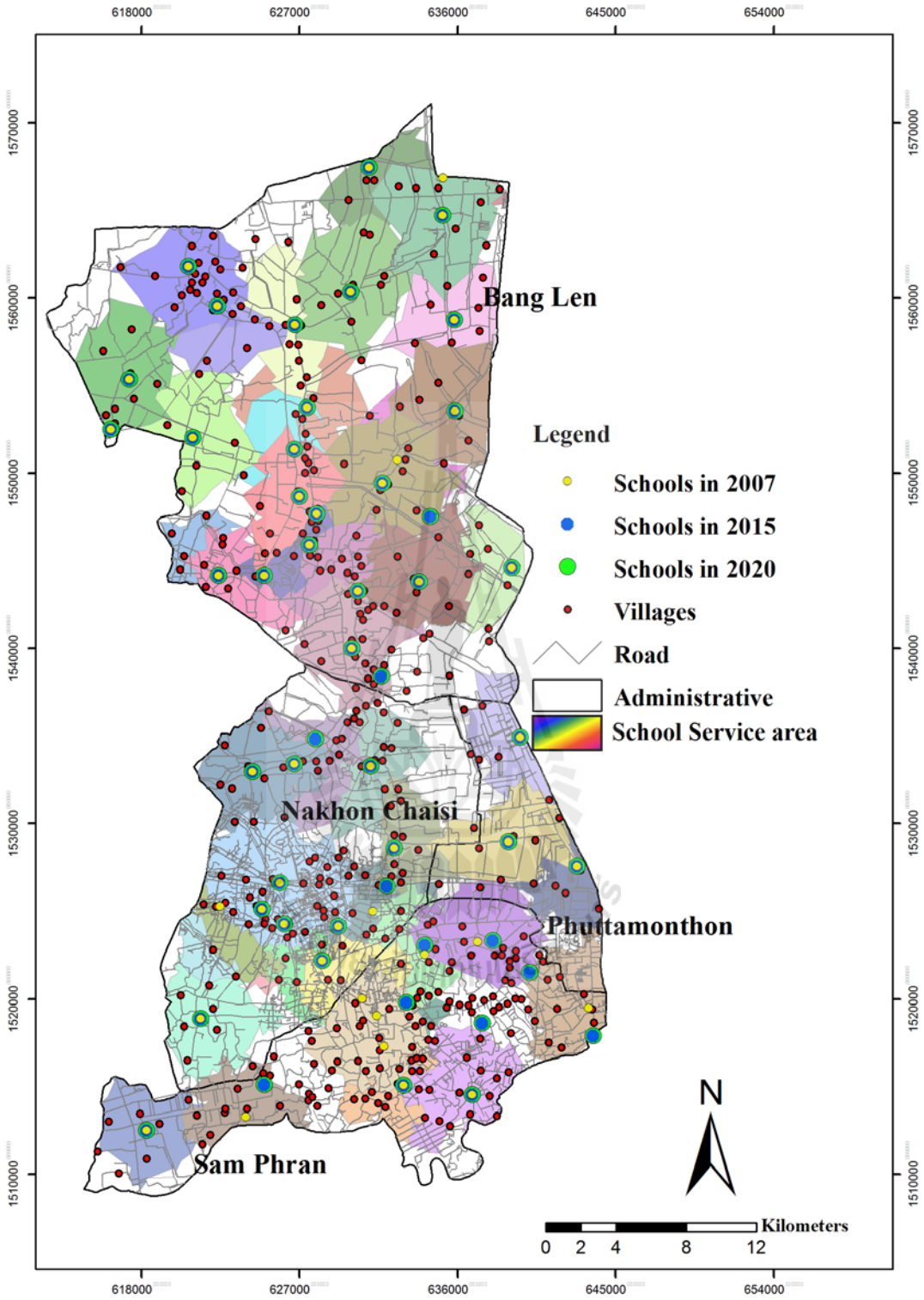


Figure 5.8b Map of school service area (5 km limit) at LS level in 2015/2020 (P-median).

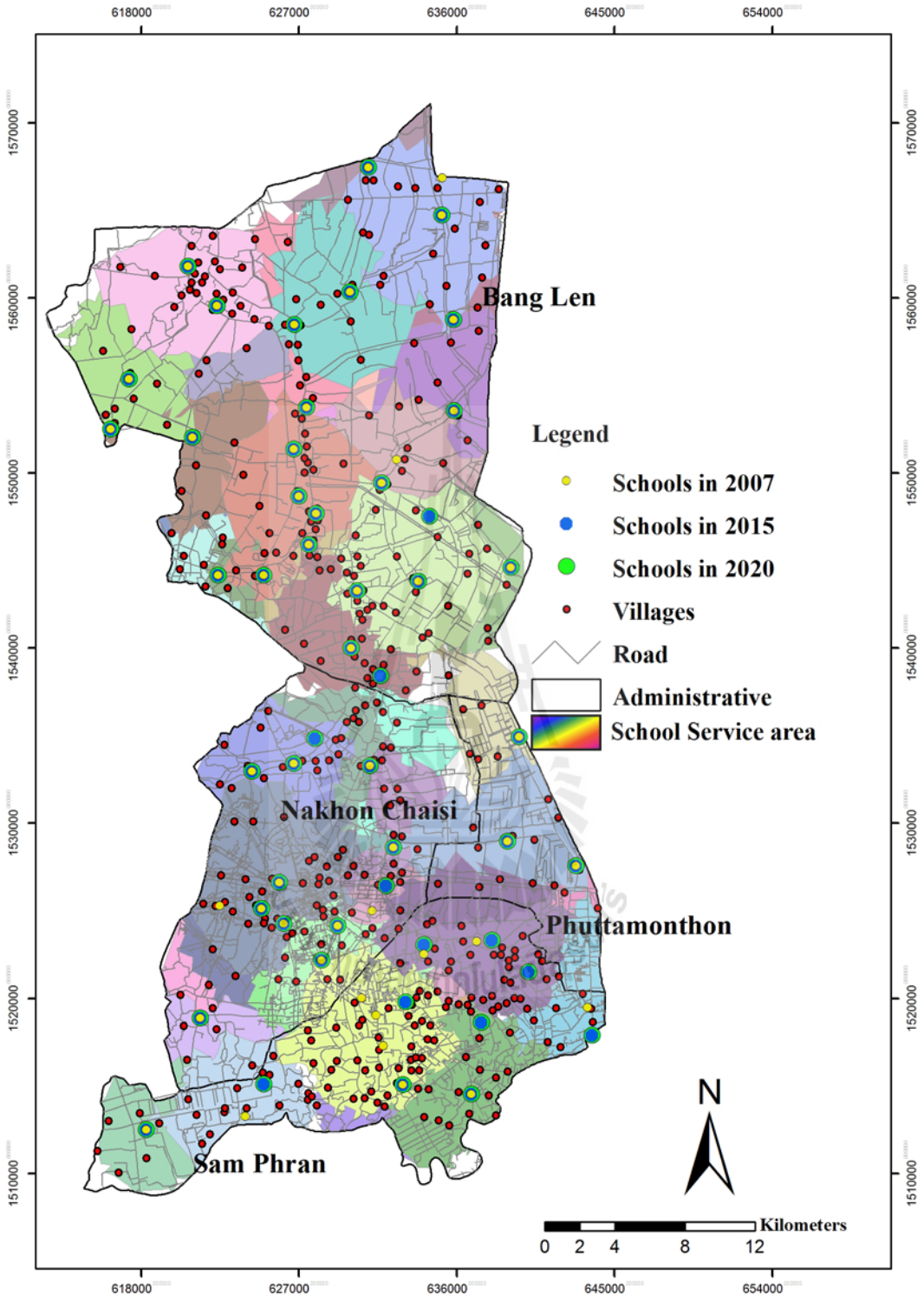


Figure 5.8c Map of school service area (7 km limit) at LS level in 2015/2020 (P-median).

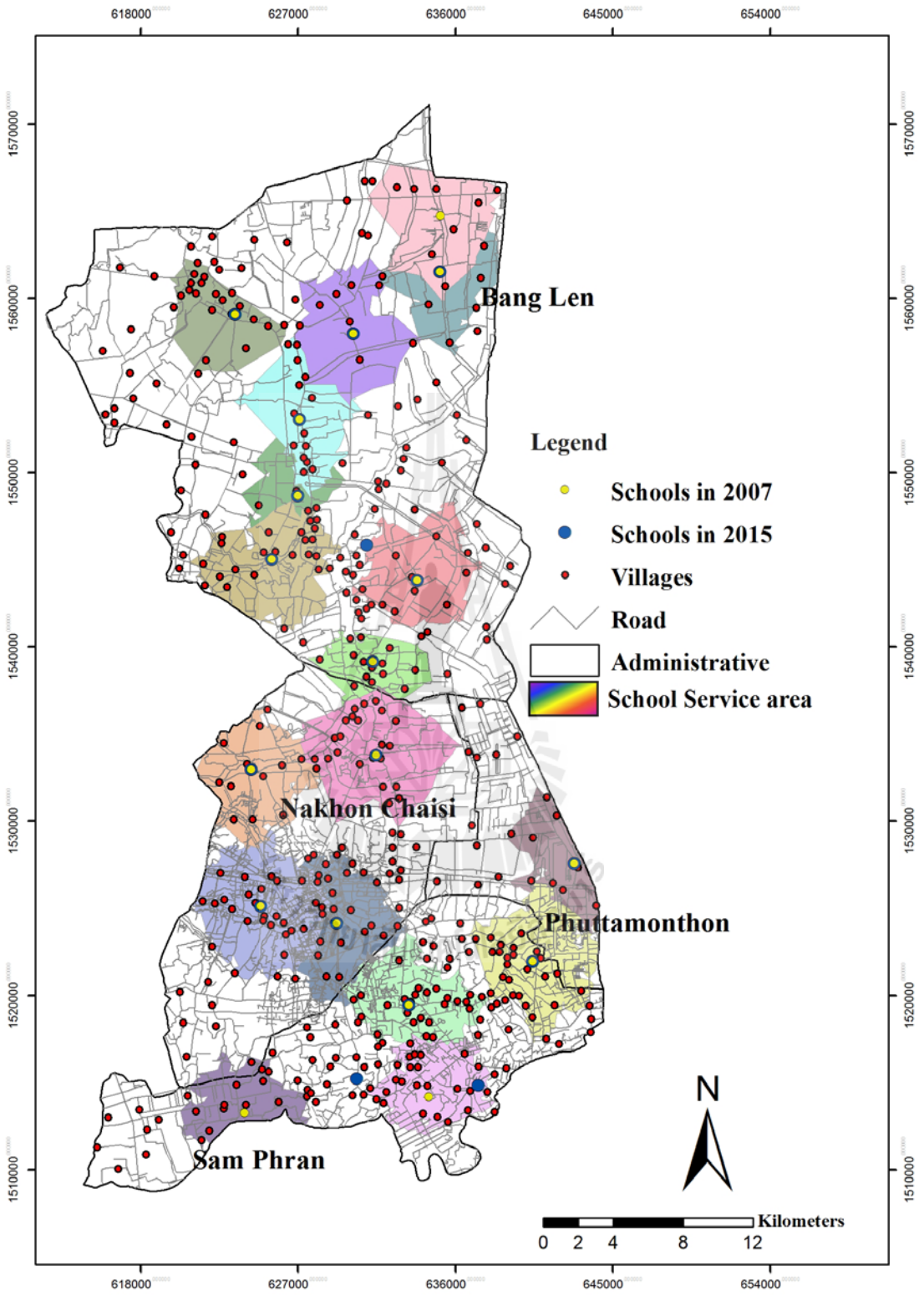


Figure 5.9a Map of school service areas (5 km limit) at US level in 2015 (P-median).

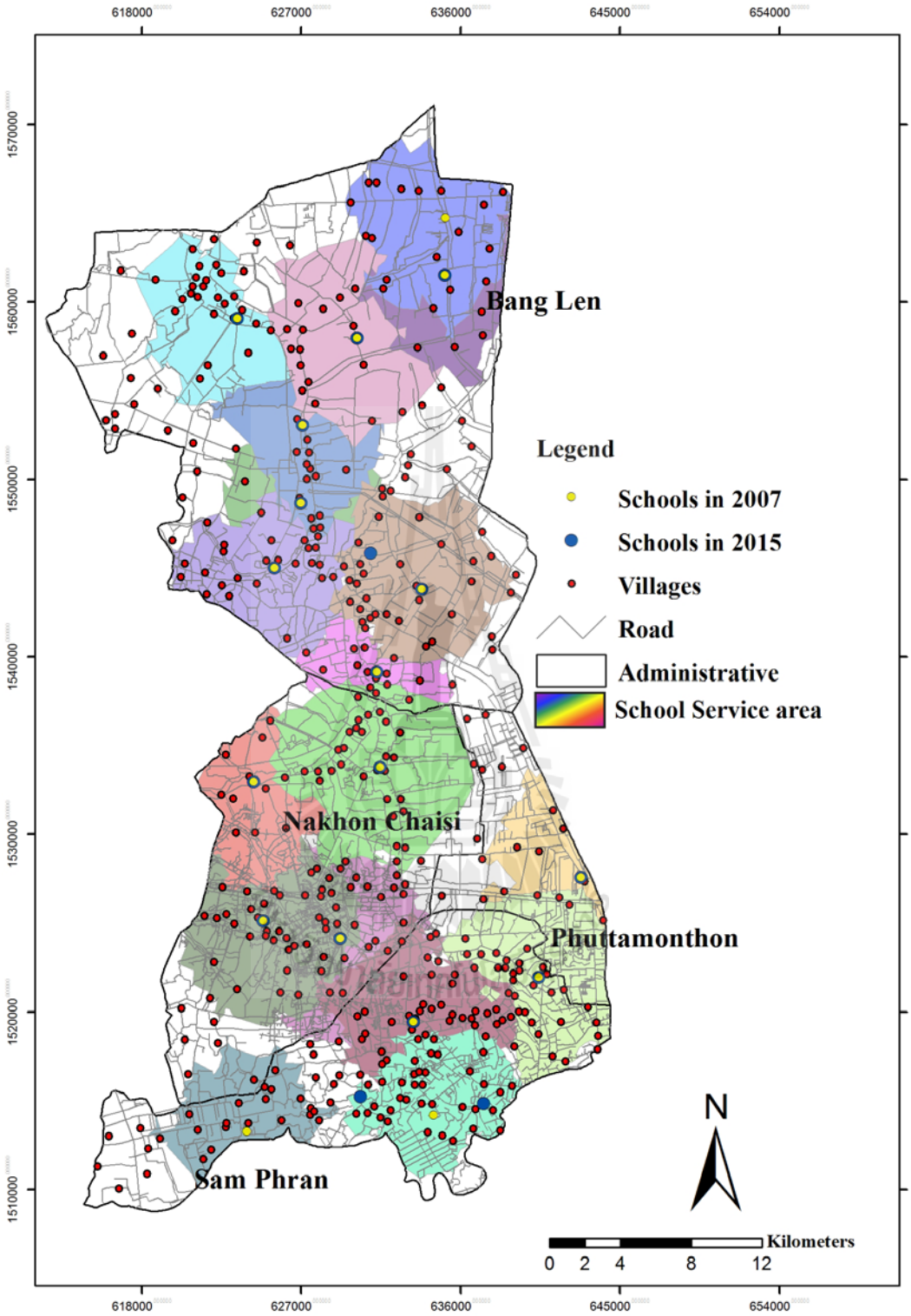


Figure 5.9b Map of school service areas (7 km limit) at US level in 2015 (P-median).

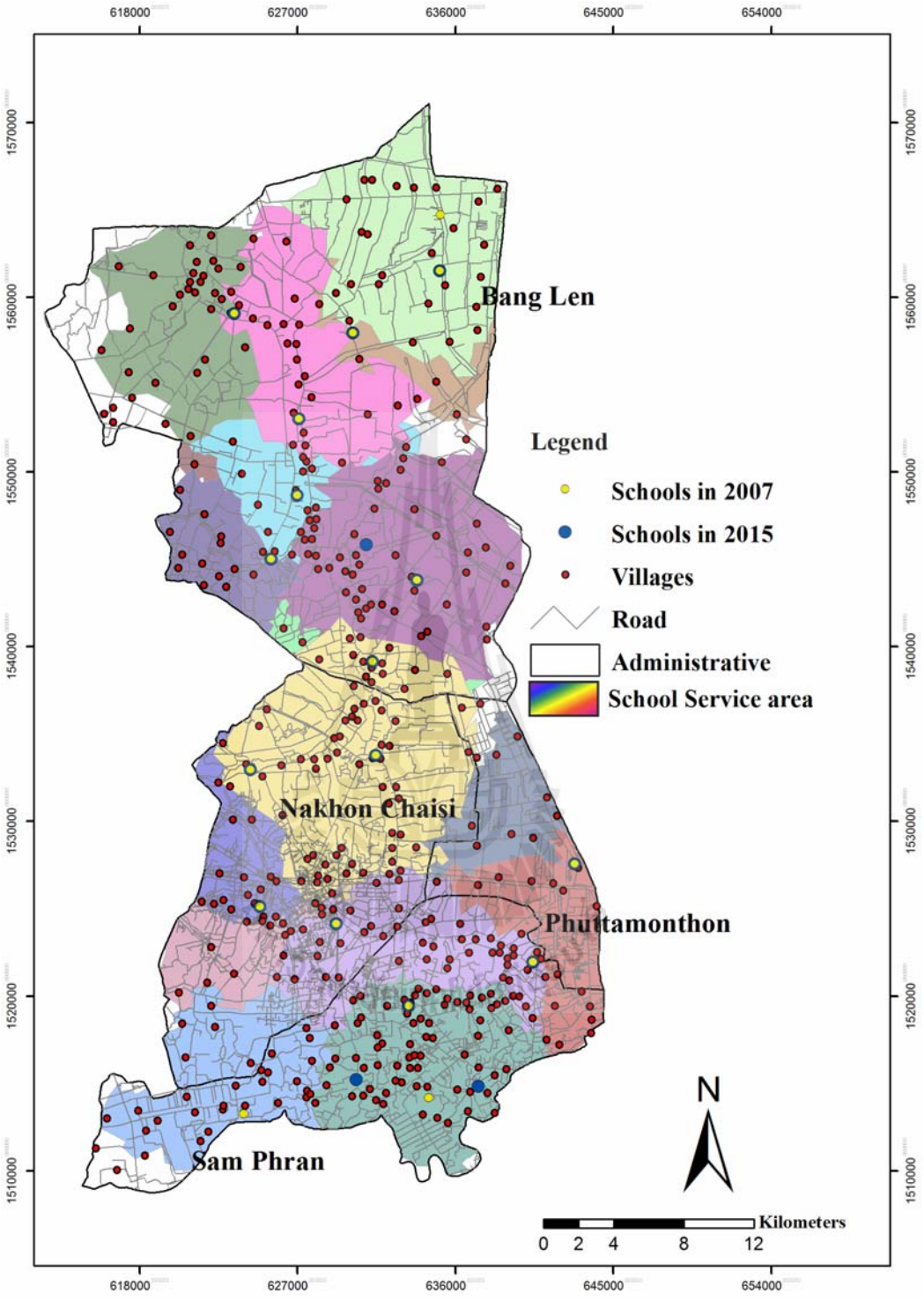


Figure 5.9c Map of school service areas (10 km limit) at US level in 2015 (P-median).

5.2 Application of Gravity P-Median Model

As mentioned in Chapter II, the gravity p-median model was developed to represent a more realistic form of a standard p-median model in which customer can choose to adopt any of the available service locations depending on the attractiveness scale of each given service site and distance from the service point and demand point (as shown in Eq. 3.5). In the thesis, a concept of the referred model was applied to the formulation of optimum school maps at US level in years 2007, 2015, and 2020 (Figure 5.10). These maps were produced based on the typical process of gravity p-median method described in Section 3.2.5. Numbers of potential and preferred school sites for each district are as described in Table 3.3. Potential sites and C values in 2015 and 2020 were assumed to be the same as those by year 2007 (as described in Table 3.6).

5.2.1 Formulation of optimum school maps

Table 5.11 presents results of the model's application at district level wherein the five lowest values of the total (and average) travel distance to school at each considered district are described while Table 5.12 provides details of the chosen school locations for the optimum case of the lowest travel distance referred to in Table 5.11 (for each district). Then, associated school maps for optimum cases (and the corresponding service areas) at each level were constructed as seen in Figure 5.10.

It was found that the chosen locations (that provide optimum travel distance) are very similar for each year of interest stated above, except at the Sam Phran District that chosen locations are different as shown in Table 5.11. As the students are not obliged to travel to the closest school as usual, the service area concept is then not applicable

Table 5.11 Lowest values of travel distance in years 2007, 2015, and 2020 (Gravity p-median).

Order (2007)	Bang Len		Nakhon Chai Si		Phutthamonthon		Sam Phran	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	21725.24	5.23	17605.90	3.84	6123.93	4.56	28002.93	3.83
2	22637.11	5.45	17701.23	3.86	6398.04	4.77	28471.96	3.89
3	22779.76	5.48	17896.17	3.91	6883.77	5.13	28603.40	3.91
4	22785.96	5.48	17902.96	3.91	7179.42	5.35	28689.82	3.92
5	23145.64	5.57	17944.67	3.92	-	-	28695.05	3.92
Order (2015)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	23211.40	5.24	18478.24	3.90	8037.45	4.53	47379.69	3.38
2	24097.52	5.44	18615.70	3.93	8436.39	4.75	47897.12	3.42
3	24211.63	5.46	18740.71	3.95	9116.62	5.13	48118.38	3.44
4	24219.52	5.46	18804.56	3.97	9523.59	5.36	48149.08	3.44
5	24636.45	5.56	18854.89	3.98	-	-	48337.97	3.45
Order (2020)	**Bang Len**		**Nakhon Chai Si**		**Phutthamonthon**		**Sam Phran**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
1	22198.54	5.20	19037.11	3.88	9217.09	4.50	57376.30	3.19
2	23126.62	5.42	19178.07	3.91	9703.93	4.74	57983.09	3.22
3	23179.80	5.43	19252.48	3.93	10510.16	5.13	57983.13	3.22
4	23258.05	5.45	19399.21	3.96	10980.37	5.36	59325.06	3.29
5	23627.93	5.54	19442.46	3.97	-	-	59529.57	3.31

Note: 1. Total ≡Total travel distance (in km), Average≡ Average travel distance per student (in km)**.**

Table 5.12 Information of the 18 selected sites at US level (Gravity p-median).

Bang Len (9) (2007, 2015, 2020)					Bang Len (9) (2007, 2015, 2020)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	M	บางเลนวิทยา	TB1	TB4	-	-	ต.บางปลา	TB4
SB12	LS/US	S	บางหลวงวิทยา	TB2	TB5	-	-	ต.บางระกำ	TB5
SB31	LS/US	S	บัวปากท่าวิทยา	TB7	TB6	-	-	ต.บางไทรป่า	TB6
SB41	LS/US	S	สถาพรวิทยา	TB11	TB9	-	-	ต.หินมูล	TB9
TB3	-	-	ต.บางภาษี	TB3					
Nakhon Chai Si (4) (2007, 2015, 2020)					**Nakhon Chai Si (4) (2007, 2015, 2020)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN21	LS/US	L	เพิ่มวิทยา	TN12	TN7	-	-	ต.ห้วยพลู	TN 7
TN5	-	-	ต.บางระกำ	TN5	TN14	-	-	ต.พะเนียด	TN 14
Phutthamonthon (1) (2007, 2015, 2020)					**Phutthamonthon (1) (2007, 2015, 2020)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TP2	-	-	ต.มหาสวัสดิ์	TP2					
Sam Phran (4) (2007)					**Sam Phran (4) (2007)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS17	LS/US	S	ปรีดารามวิทยาคม	TS6	TS3	-	-	ต.บางกระทึก	TS3
SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15	TS9	-	-	ต.อ้อมใหญ่	TS9
Sam Phran (4) (2015)					**Sam Phran (4) (2015)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TS9	-	-	ต.อ้อมใหญ่	TS9	SS15	LS/US	L	วัดไร่ขิงวิทยา	TS10
TS13	-	-	ต.ตลาดจินดา	TS13	SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15
Sam Phran (4) (2020)					**Sam Phran (4) (2020)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TS3	-	-	ต.บางกระทึก	TS3	TS13	-	-	ต.ตลาดจินดา	TS13
TS9	-	-	ต.อ้อมใหญ่	TS9	SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15

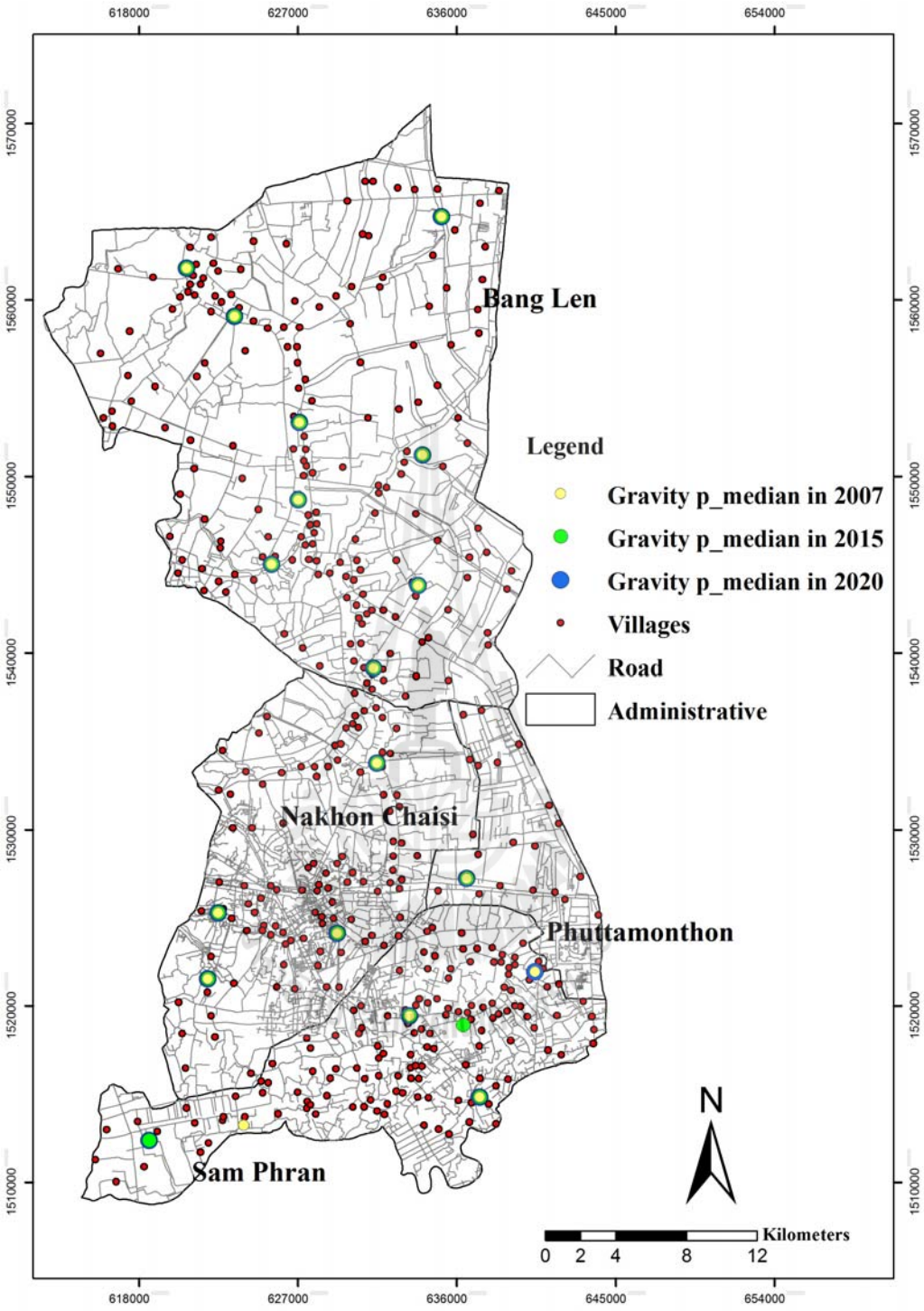


Figure 5.10 Optimum US school location map of years 2007, 2015, and 2020 (Gravity p-median).

Table 5.13 School efficiency in term of the travel distance (Gravity p-median).

Model	2007	2015	2020
P-median (km)	2.91	2.65	2.56
Gravity p-median (km)	4.22	3.86	3.80

5.2.2 School efficiency assessment

After the optimum school maps for years 2007, 2015 and 2020 were produced (as depicted in Figure 5.10), efficiency of these preferred school maps were assessed in term of the travel distance and result is shown in Table 5.13. As general concept of the gravity p-median model allows students to attend any school of their preference regardless of the travel distance, therefore, efficiency of these maps in term of the service area and service loading are not considered here as both require students to attend the closest school only.

The model gave optimum average travel distance of 4.22 km (2007), 3.86 km (2015), and 3.80 km (2020) which are much higher than those of the p-median model in the same year (Table 5.13). These differences are due to nature of the gravity p-median model that allow students to attend any school of their favor (regarding to the school's attractiveness and travel distance as described in Section 3.2.5), not only the one located closest to their residences only as required in the p-median model.

5.3 Comparison of the Results

Results from the p-median and gravity p-median models exhibited in this chapter were compared to those obtained from the previous chapter in Sections 4.2 (present) and 4.3 (idealized). Some important features are shown in Tables 5.14 and 5.15, which are:

(1) amount and locations of the preferred schools

(2) amount of the no-service and overlapped areas (village-based),

(3) number of the low SL schools, and

(4) amount of the average travel distance to school.

5.3.1 Consideration in term of the school locations

If consider in term of number of functioning schools required for these situations, the present situation has most advantage at P level with highest number of schools (127) compared to other situations (50). However, at LS and US levels, it has least number (39 and 18) when compared to those of other situations (50 and 18). However, several of the 127 existing P schools (present scenario) are classified as being small schools and mostly neglected in the formulating of P-level school maps by other methods.

It was also found that school maps (at each school level) obtained from idealized, p-median and gravity p-median models do not look particularly different much from each other. These similarities are likely resulted from the similar set of used potential sites and numbers of preferred school sites of each model. Only at the US level that the differences might be more visible especially for the idealized model and the p-median and gravity p-median models. These maps can be used to assist school zoning system if required.

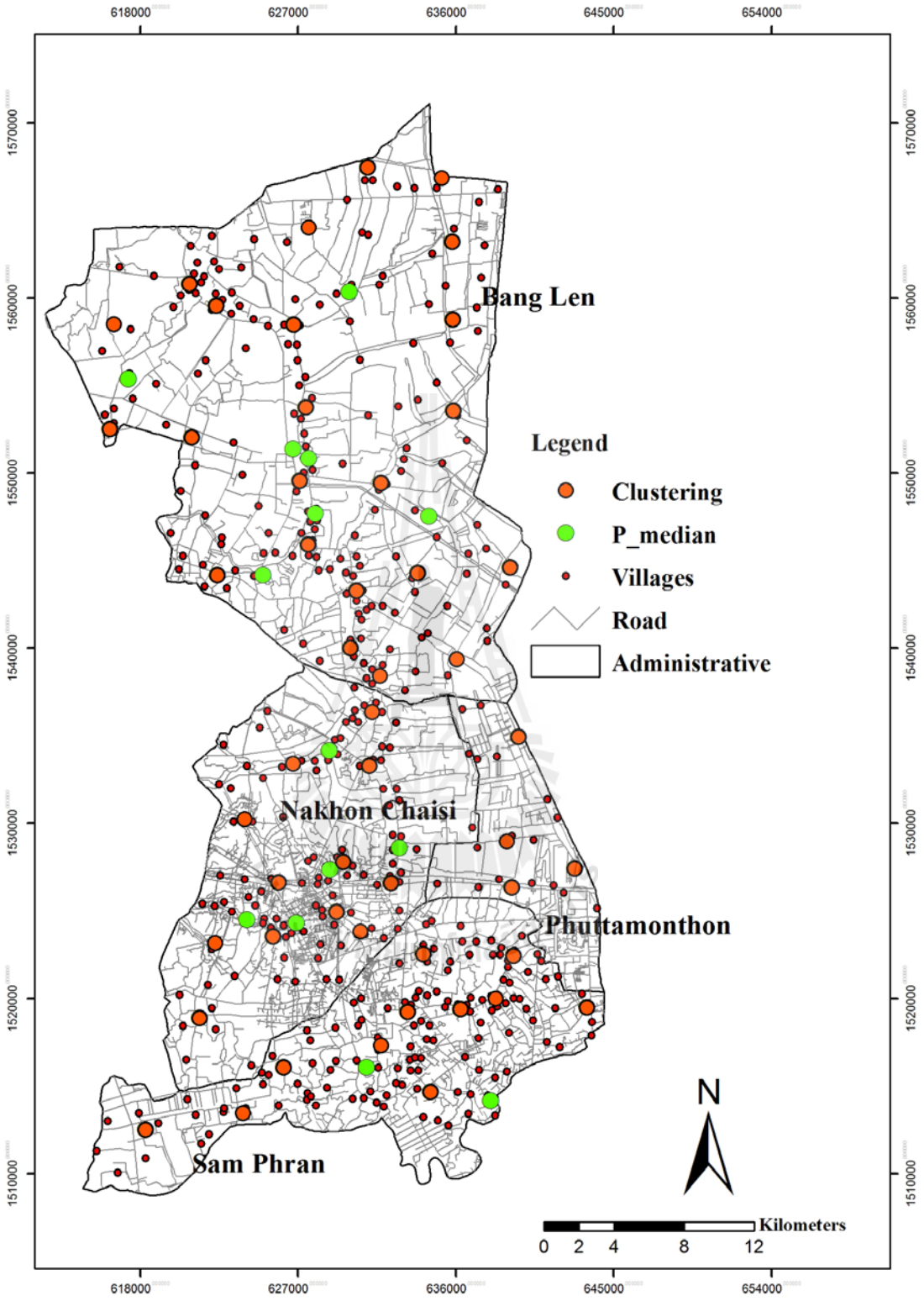


Figure 5.11a School location map at P level (idealized and p-median scenarios).

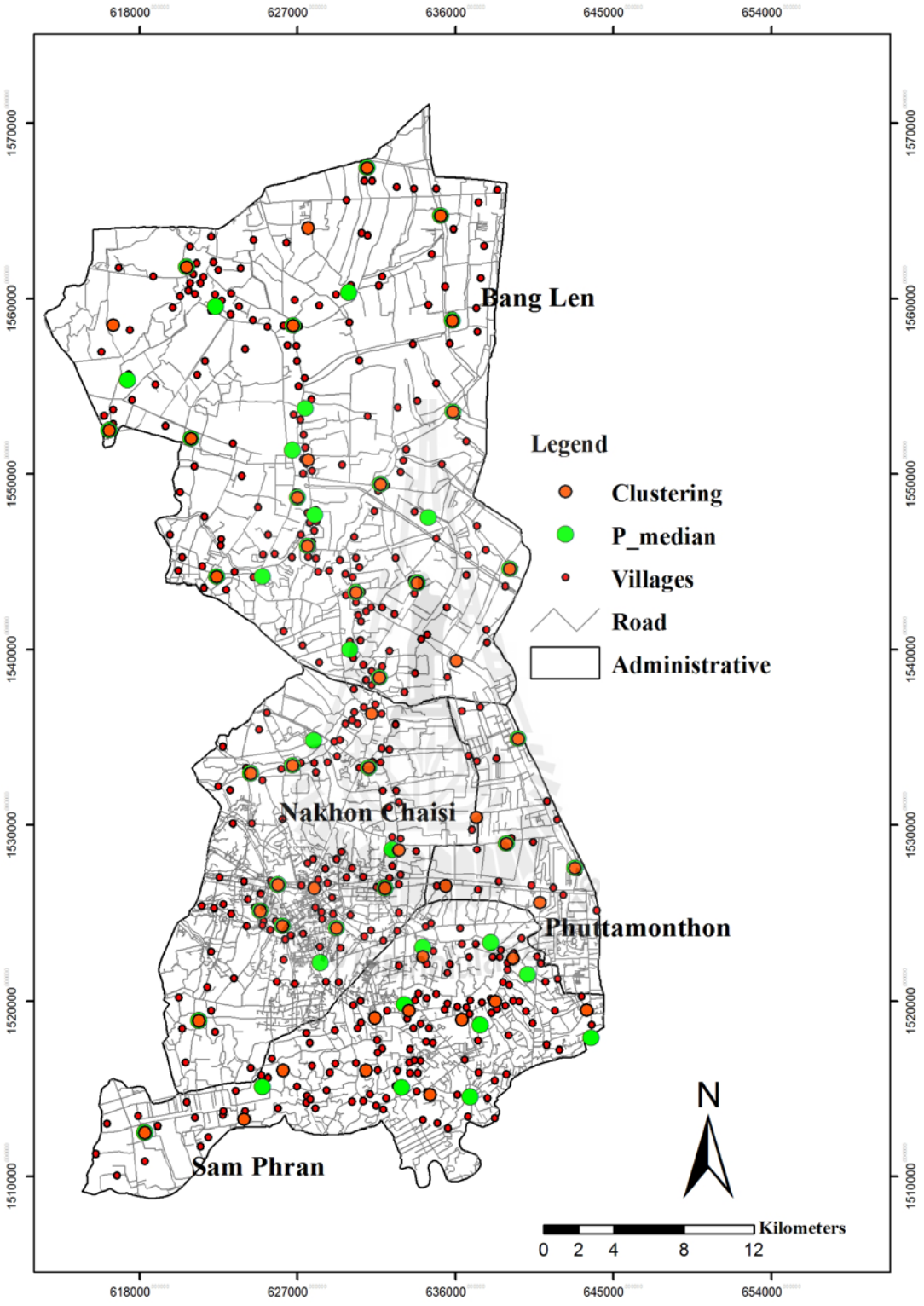


Figure 5.11b School location map at LS level (idealized and p-median scenarios).

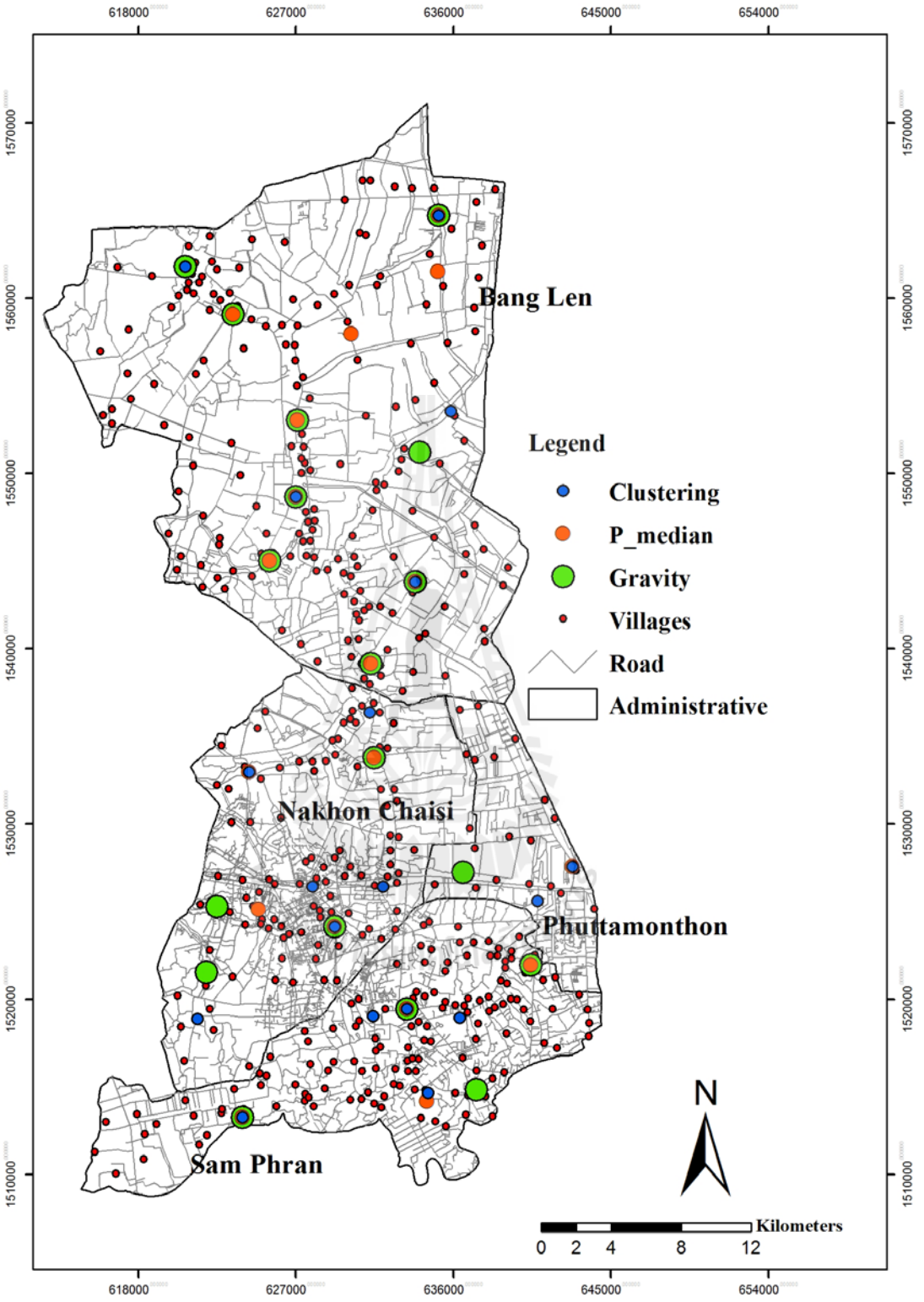


Figure 5.11c School map at US level (idealized/p-median/gravity p-median scenarios).

Table 5.14 Efficiency comparison in terms of service area and service loading (2007).

School level	No-service (%) (village-based)			Overlapped (%)			Low SL (%) (school-based)		
	PRS	**IDL**	**PMD**	**PRS**	**IDL**	**PMD**	**PRS**	**IDL**	**PMD**
P (1km)	77.43	87.81	87.36	0.45	-	-	-	-	-
P (2km)	40.86	63.43	64.56	16.48	0.90	4.74	11.02	-	-
P (3km)	11.06	35.67	38.60	49.43	9.71	15.80	33.86	6.0	8.00
P (4km)	2.26	16.25	19.64	83.07	32.96	34.76	62.20	12.0	26.00
P (5km)	0.23	5.19	8.58	94.58	60.27	55.08	79.53	34.0	42.00
LS (3km)	46.73	37.92	44.24	10.84	11.06	15.12	33.33	26.0	18.00
LS (5km)	15.80	6.32	15.35	42.66	54.63	36.34	58.97	50.0	36.00
LS (7km)	2.03	0.23	10.16	72.68	86.23	50.56	58.97	60.0	46.00
US (5km)	53.95	47.18	39.73	17.38	19.86	7.45	25.00	11.11	5.56
US (7km)	30.93	18.28	15.35	30.48	34.99	36.34	62.50	38.89	22.22
US (10km)	8.58	4.06	2.93	51.92	66.59	76.98	81.25	61.11	38.89

Note: PRS ≡ Present situation, IDL ≡ Idelaized, PMD ≡ P-median model.

Table 5.15 Efficiency comparison in term of travel distance (2007).

Distance (km)	P level			LS level			US level			
	PRS (127)	**IDL (50)**	**PMD (50)**	**PRS (39)**	**IDL (50)**	**PMD (50)**	**PRS (16)**	**IDL (18)**	**PMD (18)**	**GPMD (18)**
Maximum	5.02	7.78	8.63	8.33	7.58	7.76	13.16	12.83	12.83	27.98
Average	1.62	2.46	1.97	2.66	2.40	2.01	4.80	4.19	2.91	4.22

Note: PRS ≡ Present situation; IDL ≡ Idealized scenario; PMD ≡ P-median scenario; GPMD ≡ Gravity p-median scenario.

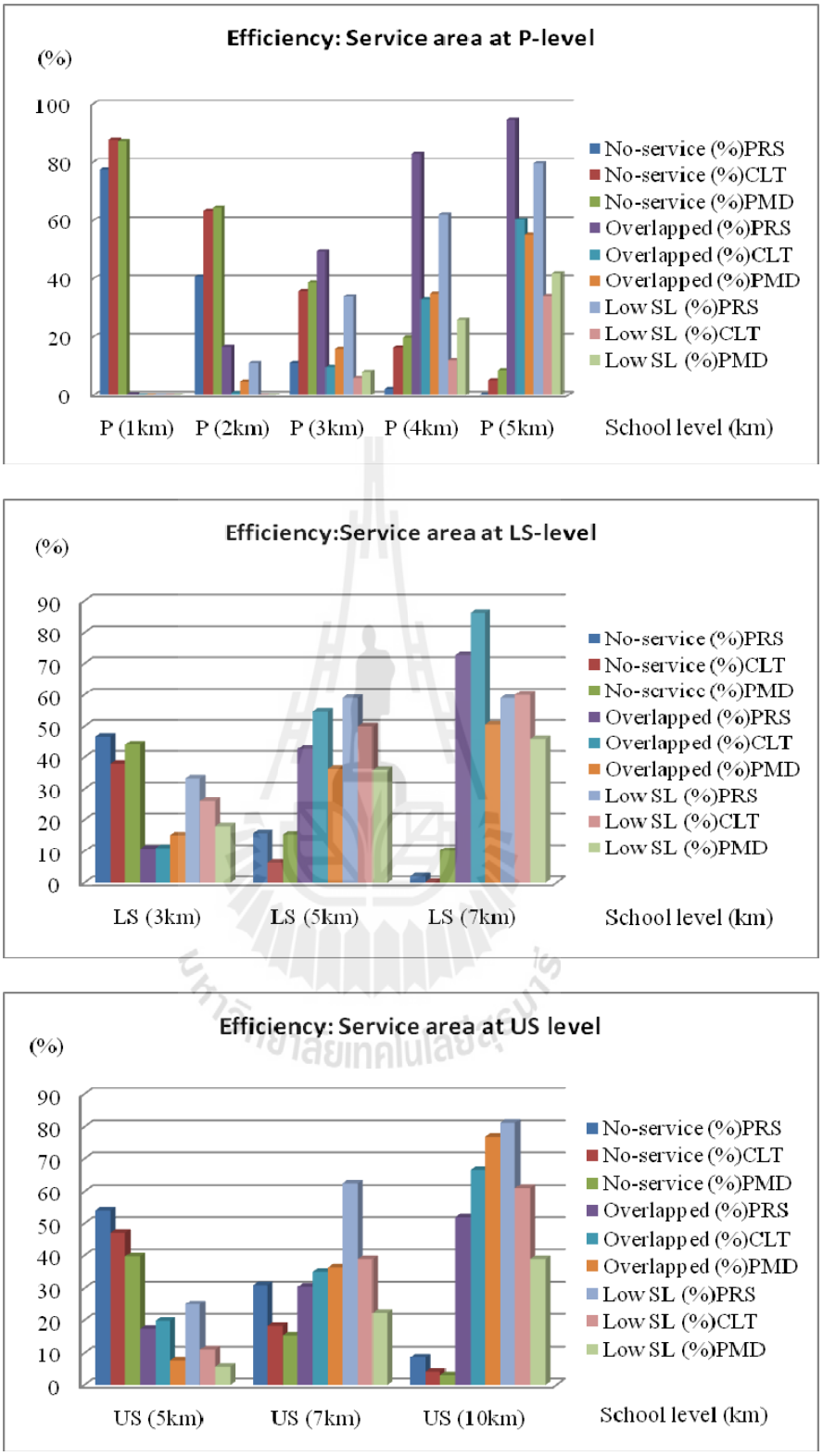


Figure 5.12 Efficiency comparisons in terms of service area/service loading (Table 5.14).

5.3.2 Consideration in term of the service area

At P-level, the present situation did the best in term of the no-service area (due to higher number of functioning schools), while the idealized and p-median scenarios did comparably well, e.g. 77.43%, 87.1%, and 87.36% (1 km limit), 40.86%, 63.43%, and 64.56% (2 km limit), and 11.06%, 35.67, and 38.60% (3 km limit). But in term of the overlapped area, the idealized scenario did best (especially at 1-3km distance limits) and the present scenario did worst due to high number of its existing schools (127).

At LS-level, the idealized scenario did best in term of the no-service area, while the present and p-median scenarios did comparably well, e.g. 37.92%, 46.73%, and 44.24% (3 km limit) or 6.32%, 15.80%, and 15.35% (5 km limit). But in term of overlapped area, present situation did best at 3 km limit (10.84%) and the p-median did worst (15.12%). However, at 5 and 7 km limits, the p-median did best (36.34% and 50.56%) while the idealized did worst (54.63% and 86.23%) though they have the same amount of functioning schools (50).

At US-level, the p-median scenario did best in term of no-service area followed by idealized scenarios, e.g. 39.73% and 47.18% (5 km limit) and 15.35% and 18.28% (at 7 km limit). In both cases, present situation did worst at 53.95% (5 km limit) and 30.93% (at 7 km limit). But in term of the overlapped area, the p-median did best at 5km limit (7.45%) while the present and idealized have comparable results (at 17.38% and 19.86%, respectively). But at 7 km and 10 km limits, the present situation did best (at 30.48% and 51.92%) followed by the idealized scenario (at 34.99% and 66.59%) and the p-median scenario (at 36.34% and 76.98%), respectively.

5.3.3 Consideration in term of the service loading

At P level, the gravity p-median did best in term the service loading as no low-SL schools appeared at all distance limits followed by the idealized and p-median scenarios, respectively while the present scenario did worst. For examples, results for the last three scenarios mentioned above are 6.0%, 8.0%, and 33.86% (3 km limit).

At LS and US levels, the p-median still did best followed by idealized scenarios while present scenario did worst. For examples, results at LS level are 18.0%, 26.0%, and 33.33% (3 km) and 36.0%, 50.0%, and 58.97% (5 km), while at the US level are 5.56%, 11.11%, and 25.0% (5 km) and 22.22%, 38.89%, and 62.5% (7 km).

5.3.4 Consideration in term of the travel distance

As shown in Table 5.15, at P level, present scenario did best in term of the travel distance (at 1.62 km) due to high number of schools (127). This follows by the p-median and idealized methods (at 1.97 and 2.46 km). On the contrary, at LS level, the p-median did best follows by the idealized and present scenario, respectively (2.01, 2.4, and 2.66 km). At US level, the p-median also did best follows by the idealized, gravity p-median and present scenario, respectively (and 2.91, 4.19, 4.39, and 4.80 km).

If consider in term of the maximum travel distance, p-median did worst at P level (at 8.63 km) while present scenario did best (at 5.02 km). But at LS level, the idealized did best (at 7.58 km) and the present scenario did worst (at 8.33 km). At US level, the gravity p-median did worst (at 27.98 km) while results of other methods are about 13 km.

5.3.5 General conclusions on school efficiency under different scenarios

From results of the comparison about school efficiency under different scenarios reported in Tables 5.14 and 5.15, the efficiency order of each considered scenario in term of the service area, service loading and travel distance is shown in Tables 5.16a and b.

Table 5.16a Efficiency order for the studied scenarios in terms of service area, service loading and travel distance (2007).

School level	No-service			Overlapped			Low SL		
	PRS	**IDL**	**PMD**	**PRS**	**IDL**	**PMD**	**PRS**	**IDL**	**PMD**
P (1km)	1	3	2	2	1	1	1	1	1
P (2km)	1	2	3	3	1	2	3	1	1
P (3km)	1	2	3	3	1	2	3	1	2
P (4km)	1	2	3	3	1	2	3	1	2
P (5km)	1	2	3	3	2	1	3	1	3
Average	1	2.2	2.8	2.8	1.2	1.6	2.6	1	1.8
LS (3km)	3	1	2	1	2	3	3	2	1
LS (5km)	3	1	2	2	3	1	3	2	1
LS (7km)	2	1	3	2	3	1	2	3	1
Average	2.67	1	2.33	1.67	2.67	1.67	2.67	2.33	1
US (5km)	3	2	1	2	3	1	3	2	1
US (7km)	3	2	1	1	2	3	3	2	1
US (10km)	3	2	1	1	2	3	3	2	1
Average	3	2	1	1.33	2.33	2.33	3	2	1

Note: PRS ≡ Present situation, IDL ≡ Idelaized, PMD ≡ P-median model.

1 ≡ First best, 2 ≡ Second best, 3 ≡ Third best.

Table 5.16b Efficiency order for the studied scenarios in term of travel distance (2007).

Distance	P level			LS level			US level			
	PRS (127)	**IDL (50)**	**PMD (50)**	**PRS (39)**	**IDL (50)**	**PMD (50)**	**PRS (16)**	**IDL (18)**	**PMD (18)**	**GPMD (18)**
Maximum	1	2	3	3	1	2	3	1	1	4
Average	1	3	2	3	2	1	4	2	1	3
Average order	1	2.5	2.5	3	1.5	1.5	3.5	1.5	1	3.5

Note: PRS ≡ Present situation; IDL ≡ Idealized scenario; PMD ≡ P-median scenario; GPMD ≡ Gravity p-median scenario.

Table 5.17 Accumulative scores for efficiency orders appeared in Table 5.16a and b.

School level	PRS	IDL	PMD
P	7.40	6.90	8.70
LS	10.01	7.50	6.50
US	10.83	7.83	5.33

It can be seen from Table 5.16a that, based on the average value of the efficiency order, at P-level, the present scenario did best in term of the no-service area while the idealized scenario did best in term of the overlapped area and the low SL aspect. At LS level, the idealized scenario did best in term of no-service area but the present scenario (along with the p-median scenario) did best in term of overlapped area while p-median scenario did best in term of the low SL aspect. At US level, the p-median scenario did best in term of the no-service area, as well as in term of the low SL aspect, while the present scenario did best in term of the overlapped area. And from Table 5.16b (in term of the travel distance), the present scenario did best at P

level, while idealized scenario did best at LS level (along with p-median scenario) and p-median did best at US level.

If the efficiency orders of each relevant scenario given in Table 5.16a and b were combined, results can be found as seen in Table 5.17. It can be initially concluded from these data that the idealized scenario should be mostly preferred in operating education at the P level (followed by the present and p-median scenarios, respectively). However, at the LS level, the p-median scenario should be mostly preferred (followed by the idealized and present scenarios, respectively). Similarly, at US level, the p-median scenario should be mostly preferred (followed by the idealized and present scenarios, respectively).

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CHAPTER VI

CONCLUSIONS AND SUGGESTIONS

Main purpose of this thesis is to demonstrate capability of the GIS technology and location-allocation models (p-median and gravity p-median) in the preparation of suitable school location maps at the district level in local Thailand. The study area is Educational Service Area Office 2 in Nakhon Pathom Province which is covering 4 districts (Bang Len, Nakhon Chai Si, Phuttamonthon, and Sam Phran), 58 sub-districts (or tambons) and 443 villages with area coverage of approximately 1,139.2 km^2 (Figure 1.1 and Table 1.1). There were 143 schools included in the study (mostly at the primary level).

The research consists of three main parts. The first part is about the development of relevant GIS database that are necessary for the subsequent school mapping analysis. These data were acquired from their responsible sources or field surveys and categorized into three broad groups: general data, school data, and tambon/village data (as described in Table 3.1). In the second part, efficiencies of the existing schools (at primary, lower-secondary and upper-secondary levels) were assessed in terms of the service area, service loading, and travel distance to school. Comprehensive details of the assessment process are described in Chapter III. These results were then compared with those obtained from the other two methods: idealized and p-median. In the third part, gravity p-median was applied to school mapping. Optimal school location map for 2015 and 2020 were also created and assessed for

efficiencies using p-median and gravity p-median models.

6.1 School Efficiency Assessment for Present Situation

From the results, it is obvious that numbers of no-service villages are significantly reduced when distance limits increase. For example, at P level, percentage of no-service village decreases from about 77.43% to 11.6% and 0.23% when the distance limit increases from 1 to 3 and 5 km, respectively. However, the expansion of defined service area can greatly raise number of the service-overlapping villages; e.g. at P level, percentage of the overlapped village increases from about 0.45 to 49.43 and 94.58 when a distance limit changes from 1 to 3 and 5 km, respectively. Most overlapped villages (at all levels) are under services of 2-5 schools simultaneously.

It is interesting to find that at the distance limit of 3 km (for P and LS levels) and 5 km (for US level) that are preferred by state's policy, the no-service villages become 11.06%, 46.73%, and 53.95%, while the overlapped villages become 49.43%, 10.84%, and 17.38%, respectively. These numbers indicate that present positions of the existing primary schools are relatively sufficient to provide education for the whole study area at 3km-limit criteria (with about 90% coverage), but the overlapped villages of 49.43% (at this limit) implies that the number of the existing schools is too high resulted in the relatively crowded school distribution. On the contrary, at distance limits of 3 km (for LS level) and 5 km (for US level), numbers of no-service villages are still relatively high (at 46.73% and 53.95%, respectively) but numbers for those with overlapping services are rather low (at 10.84%, and 17.38%, respectively). This means the current positions of the concerned LS and US schools are considerably well

located but their numbers are still not sufficient to serve most villages existing in the area (at the given distance limits).

The possible solutions for this situation are the increases in number of LS and US schools and/or values of distance limit. For examples, if the distance limits become 5 km (for LS level) and 7 km (for US level), numbers of the observed no-service villages will be reduced to be 15.80% and 30.93%, respectively, while those of the overlapped villages shall become 42.66% and 30.48%, respectively.

In term of service loading, it was found that general trend of SL values (at each school level) depends critically on the distance limits where higher limit leads to lower number of SL. For examples, at P level, numbers of schools at Low-SL level increase from 14 at 2km limit to 43 (3 km), 79 (4 km), and 101 (5 km), respectively. And at limits of 3 km (for P/LS levels) and 5 km (for US level) preferred by the state's policy, numbers of schools with low SL become 43 (33.86%), 13 (33.33%), and 2 (12.50%), respectively, whereas numbers of schools with very high SL values become 16 (12.60%), 10 (25.64%), and 5 (31.25%). These results indicate that at these preferred distance limits, numbers of schools with low SL values are still relatively high, especially at P level. This might be due to large number of P schools residing in the area (127) that leads to the potential low rate of attending to the comparatively less attractive ones situating in the area.

In term of the average travel distances under PR-1 and PR-2 criteria (as described in Table 4.8) are 1.62 and 2.63 km, respectively, but these values rise to 2.66 and 4.84 km at LS-level and 4.80 and 10.56 km for US level. This means students have to travel longer if level of the school increases (from P to LS and then US). The found value of 1.62 km at P-level (of PR-1 scenario) is reasonably acceptable for the

walking and cycling modes of traveling to school, and values of 2.66 and 4.80 km at LS and US levels (of PR-1 scenario) are rather practical for the cycling and motor-vehicles-based modes of traveling for most students at these levels.

However, it is evident that average travel distances at all school levels of the PR-2 scenario are noticeably higher than those of the PR-1 scenario (about 60% at P level, 90% at LS level, and 120% for the US level). These differences are more obvious in term of the gained maximum travel distance. For examples, maximum distance values at P and US levels of the PR-1 case are only 5.02 and 13.16 km, compared to those of the PR-2 case, which are 29.42 and 39.92 km, respectively. Based on these obtained results, it could be primarily concluded that the present school zoning system authorized by the responsible state's agency is still rather ineffective in reducing average travel distance of the students at all educational levels when compared to the simple strategy of assigning the students to their existing closest schools (along road network) only.

6.2 School Efficiency Assessment based on Idealized Method

In term of the service area, it is obvious that numbers of villages with no service provided are significantly reduced when distance limits of the service area increase. For example, at P level, percentage of no-service village reduces from about 87.81 to 35.67 and 5.19% when distance limit rises from 1 to 3 and 5 km, respectively. Similar trends occur at the LS and US level also. However, the expansion of defined service area may result in notably higher amount of the service-overlapping villages; e.g. at P level, number of the overlapped village increases from about 0 to 9.71 and 60.27% when the distance limit changes from 1 to 3 and 5 km, respectively. Most

overlapped villages are under service of 2-5 schools simultaneously.

At the distance limits of 3 km (for P and LS levels) and 5 km (for US level) that are in favor by the state policy, the no-service areas become 35.67%, 37.92%, and 47.18%, while overlapped areas become 9.71%, 11.06%, and 19.86%, respectively. These numbers indicate that the selected primary schools can provide services to about 2/3 of all villages and about 1/3 of them are still off service (at 3 km distance limit). This number is notably higher than the present situation (at 11.06%). But the overlapped villages of about 9.71% infer the relatively well-placed locations of the selected schools. This number decreases dramatically from one obtained from idealized method (49.43%) due to great reduction in number of the relevant primary schools (from 127 to 50).

Similarly, at distance limits of 3 km (LS level) and 5 km (US level), numbers of the no-service villages are about 1/3 and 1/2 of the total village numbers, respectively. These results mean that the preferred number and/or positions of the LS and US schools are still not sufficient, or appropriate, to contribute school services to most villages residing in the area (at these distance limits) as primarily required.

In term of service loading, it was found that higher distance limit leads to lower number of SL as expected (at all school levels). And at preferred distance limits of 3 km (for P and LS levels) and 5 km (for US level), numbers of the low SL schools (L) become 3 schools (6.0%), 13 schools (26.0%), and 0 schools (0%), respectively, while numbers of the very high SL schools (VH) become 14 schools (28.0%), 9 schools (18.0%), and 5 schools (27.78%), respectively. These results indicate that at these distance limits; percentages of the considered school with low SL values drop dramatically by idealized method at the P level (from 33.86 to 6%) but they are rather

comparable at the LS level (from 33.33% to 26%), and noticeably decreased at the US level (from 12.85% to 0%). This should be due to large drop in number of the functioning primary schools (from 127 to 50) where most of the discarded ones are the small-scale schools (according to criteria described in Section 3.2.3). Relatively high proportion in number of schools with moderate/high/very-high SL values (at all levels) indicates capability of the used idealized technique to abolish the relatively low SL ones and to encourage higher service capability to most functioning schools still exist in the study area (after applying the idealized method).

In term of the travel distance, the result indicates that average travel distances of the students (by idealized method) are 2.46 km (at P level), 2.40 km (at LS level), and 4.19 km (at US level). The average value of 2.46 km (with the maximum of 7.78 km) at P level is notably higher when compared to those of present situation (with average 1.62 km and maximum 5.02 km) due to great drop in number of functioning schools (from 127 to 50). However, these numbers should still be reasonably acceptable for the cycling or motor-vehicle using modes of travelling to school (for the students).

The average values of about 2.40 km (with maximum value of 7.58 km) at the LS level, and 4.19 km (with maximum value of 12.83 km) at US level, are rather comparable to those obtained in present scenario (average 2.66 km/maximum 8.33 km at the LS level and average 4.80 km/maximum 13.16 km at the US level). These should be due to similar numbers of considered schools (39 to 50 at LS level and 16 to 18 at US level) where most existing old schools at both levels (except ones with rather low SL values) were still functioned in the idealized scenario. This makes school's location maps (before and after applying idealized method) do not look much different from each other (at each level).

6.3 School Efficiency Assessment based on P-Median Model

In term of service area, numbers of no-service villages are significantly dropped with increasing distance limits while numbers of overlapped villages substantially grow. And like in the idealized or present scenarios, most overlapped villages (at all levels) are associated with 2-5 schools simultaneously. At the distance limits of 3 km (for P and LS levels) and 5 km (for US level) preferred by the state's policy, no-service villages become 38.60%, 44.24%, and 39.73%, and overlapped ones are 15.80%, 15.82%, and 7.45%, respectively. These numbers indicate that the selected schools locations still cannot provide services to most villages found in the area under these distance limits (about 40% of them are still left out) while the overlapping problem should not be of much concerned. The high value of no-service area at LS level (44.24%) should be of particular concerned.

The no-service problem can be substantially solved if the preferred distance limits are extended, for examples, from 3 km to 5 km at P and LS levels and from 5 km to 7 km at US level. This modification will result in much smaller numbers of no-service villages, which are 8.58% (P level) and 15.35% (LS and US levels). Otherwise, more new schools are required at all educational levels of interest.

In term of service loading, it was evident that higher distance limit shall lead to higher number of the schools with low SL (at all school levels) as expected. At distance limits of 3km for P and LS levels and 5km for US level, numbers of school with low SL values (0-50) are about 8.0%, 18.0%, and 0.0%, respectively. This result indicates that the p-median method can generate fairly satisfied result in term of reducing number of schools with relatively low SL values and promoting the moderate/high SL ones.

In term of the travel distance, it was found that that average travel distances of the students are 1.97 km (P level), 2.01 km (LS level), and 2.91 km (US level). The average value of 1.97 km (with maximum of 8.63 km) at P level may be rather higher than that of the present situation (average 1.62 km and maximum 5.02 km) due to significant drop in number of the functioning schools (from 127 to 50). However, these values should be still reasonably acceptable nowadays for the cycling or motor-vehicle modes of travelling to school of students. However, in the walking mode of travel students may be able to find some shorter routes (not on the major road network) that can take them to their schools at shorter distances than the found average value of about 2 km mentioned here.

The average values of 2.01 km (with maximum of 7.76 km) at LS level, and 2.91 km (with maximum of 12.83 km) at US level, are significantly lower than those obtained from the present situation (average 2.66 km/maximum 8.33 km at LS level and average 4.80 km/maximum 13.16 km at US level). These should be due to the initial conditions of the model that try to determine a specific set of school locations that provide minimum average travel distance to students, though numbers of schools preferred at these levels are rather comparable (39 to 50 at LS level and 16 to 18 at US level) and most existing schools at both levels were still retained by p-median method.

In addition, it was found that the optimum school maps for years 2015 and 2020 do not look much different from each other (and from those for 2007). These similarities is responsible for outcome of the analysis which evidenced that their general efficiencies in term of service area (no-service and overlapped service) and average travel distance to school are also not different much from each other.

6.4 School Efficiency Assessment based on Gravity P-Median Model

After the optimum school maps for years 2007, 2015, and 2020 were produced, efficiency of these preferred school locations were evaluated in term of the travel distance alone. Like situation seen in case of p-median model, it was found that the generated optimum school maps of years 2015 and 2020 (at each school level) are not different much from each other and from those of year 2007. These similarities are likely to come up from the same set of used potential sites and numbers of population (at village level) that do not differ much during years 2007-2020 (except in some areas). Due to the similarity of optimum school maps created for all these years (2007, 2015, and 2020), their general efficiencies in the travel distance term are also not different much from each other.

IF compare with the gained results of the p-median model for years 2007, 2015, and 2020, the gravity p-median model does rather more poorly, e.g. 4.39 km to 2.91 km (2007) or 3.80 km to 2.56 km (2020).

6.5 Comparison of the Results

Results from the p-median and gravity p-median models were compared to those obtained from the present and idealized scenarios in terms of:

(1) amount and locations of the preferred schools,

(2) amount of the no-service and overlapped areas (village-based),

(3) number of the low SL schools, and

(4) amount of the average travel distance to school.

In term of number of functioning schools required for these situations, the present situation has most advantage at P level with highest number of schools (127) compared to other situations (50). However, at LS and US levels, it has least number (39 and 18) when compared to those of other situations (50 and 18). However, several of the 127 existing P schools (present scenario) are classified as being small schools and mostly neglected in the formulating of P-level school maps by other methods.

It was also found that school maps (at each school level) obtained from idealized, p-median and gravity p-median models do not look particularly different much from each other. These similarities are likely resulted from the similar set of used potential sites and numbers of preferred school sites of each model.

In term of the service area, at P-level, the present situation did best in term of the no-service area (due to high number of schools), while idealized and p-median scenarios did comparably well, e.g. 77.43%, 87.1%, and 87.36% (at 1 km limit), 40.86%, 63.43%, and 64.56% (at 2 km limit), and 11.06%, 35.67%, and 38.60% (at 3 km limit). However, in term of the overlapped area, the idealized scenario did best (especially at 1-3 km limits) and the present scenario did worst due to high number of its existing schools (127).

At LS-level, the idealized scenario did best in term of the no-service area, while the present and p-median scenarios did comparably well, e.g. 37.92%, 46.73%, and 44.24% (3 km limit) or 6.32%, 15.80%, and 15.35% (5 km limit). But in term of overlapped area, present situation did best at 3 km limit (10.84%) and the p-median did worst (15.12%). However, at 5 and 7 km limits, the p-median did best (36.34% and 50.56%) while the idealized did worst (54.63% and 86.23%) though they have the same amount of functioning schools (50).

At US-level, the p-median scenario did best in term of the no-service area follows by idealized scenarios, e.g. 39.73, 47.18 (5 km limit) and 15.35, 18.28 (at 7 km limit). In both cases, present situation did worst at 53.95% (5 km limit) and 30.93% (7 km limit). But in term of the overlapped area, p-median did best at 5 km limit (7.45%) but at 7 km and 10 km limits, the present situation did best (at 30.48% and 51.92%).

In term of service loading, at P level, the idealized method did best followed by the p-median scenarios while the present scenario did worst. For examples, results for the methods mentioned above are 6.0%, 8.0%, and 33.86% (3 km limit), 12.0%, 26.0%, and 62.2% (4 km limit) and 34.0%, 42.0%, and 49.53% (5 km limit), respectively. At LS and US levels, the p-median did best followed by the idealized method while present scenario did worst. For examples, results at LS level are 18.0%, 26.0%, and 33.33% (3 km), 36.0%, 50.0%, and 58.97% (5 km), and US level are 5.56%, 11.11%, and 25.0% (5 km), 22.22%, 38.89%, and 62.5% (7 km).

In term of the travel distance, at P level, present scenario did best in term of the travel distance (at 1.62 km) due to high number of schools (127). This follows by the p-median and idealized methods (at 1.97 and 2.46 km). On the contrary, at LS level, the p-median did best follow by the idealized and present scenario, respectively (2.01, 2.4, 2.66 km). At US level, the p-median also did best follows by the idealized, gravity p-median and present scenario, respectively (2.91, 4.19, 4.39, 4.80 km).

If consider in term of the maximum travel distance, p-median did worst at P level (at 8.63 km) while present scenario did best (at 5.02 km). But at LS level, the idealized did best (at 7.58 km) and the present scenario did worst (at 8.33 km). At US level, the gravity p-median did worst (at 27.98 km) while results of other methods are about 13 km.

6.6 Suggestions

The works presented in this thesis still have some shortcomings due to the applied assumptions and the methods used to determine school's efficiencies, which should be of particular interest in further study of this kind. These are (for examples):

(1) The SL derivation method might lead to an under-estimation of the SL values for schools whose service areas being overlapped as, under this situation, these schools have to compete with each other for having students living over the overlapping area to attend their school and have to regard all potential students found in that area to be their target group which is not true in practice. As a consequence, the interpretation of school's efficiency in term of the SL values should be done cautiously with this fact in mind.

(2) The strict school's service area policy is still not implemented in Thailand and students can attend any schools available to them regardless of the actual travel distance. By doing so, the students' behavior will introduce substantial difficulty in the interpretation of school's SL value properly as its actual students can come from many villages locating outside their service areas not mainly from potential students residing in its service area as primarily assumed.

The student' performance, moreover, could also result in the potential longer travel distance to school (average value) than ones gained in the PR-1 case.

(3) The students may take shorter routes to travel to school that do not include in the available road network maps (especially at P and LS levels or for walking/cycling modes of travel). This could introduce potential shorter travel distance to school (average value) than one being obtained by using only formal road network. This issue is significant and should be investigated more thoroughly especially at the

primary level.

(4) Limit of school capacity is still not included in the present analysis as it was only concerned about travel distance. In case of the factor is considered, the average travel distance might be notably increased from the current obtained values. This is because all schools have practical limit of their own on the potential number of students affordable to them, therefore, if the closest schools are not available to the students; they then have to travel longer to the new available schools within the area. As a result, school's capacity should be included if more realistic school maps are needed.

However, limit of school's loading capacity can be purposely improved if state need to fully implement the strict school's zoning system that requires students to simply attend the closest available schools to their residences.

(5) All potential students were assumed to attend the state-run schools which is not true as in reality only about 70-80% of total students (at each level) attend state-run schools while most of the remaining private schools locating in the area. Moreover, a lot of potential students may not have chances to go to school as expected, which makes real number of the attending rate lower than what should be in the considering ideal cases. Hence, knowledge on actual school's attending rate may help in finding more valid data of school's efficiencies, especially, in term of the service loading.

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APPENDICES

APPENDIX A

GENERAL INFORMATION AT TAMBON LEVELS

Table A1.1 General data for Bang Len District (listed by tambon).

Code	Official name		POP (2007)	Area (km^2)	POP density	Number of	
	English	Thai				VIL	SCH
TB1	Bang Len	บางเลน	10,850	48.96	221.61	12	5
TB2	Bang Luang	บางหลวง	9,083	40.65	223.44	21	7
TB3	Bang Phasi	บางภาษี	9,307	37.42	248.72	13	6
TB4	Bang Pla	บางปลา	6,674	85.98	77.39	15	3
TB5	Bang Rakam	บางระกำ	9,151	36.46	250.99	15	3
TB6	Bang Sai Pa	บางไทรป่า	5,806	21.96	264.39	10	2
TB7	Bua Pak Tha	บัวปากท่า	4,450	23.76	187.29	5	5
TB8	Don Tum	ดอนตูม	4,674	25.51	183.22	11	3
TB9	Hin Mun	หินมูล	5,874	55.84	105.19	12	2
TB10	Khlong Nok Krathung	คลองนกกระทุง	3,688	44.07	83.69	11	2
TB11	Lam Phaya	ลำพญา	4,177	19.66	212.46	11	3
TB12	Naraphirom	นราภิรมย์	4,754	33.45	142.12	11	4
TB13	Nin Phet	นิลเพชร	4,357	30.15	145.51	10	2
TB14	Phai Hu Chang	ไผ่หูช้าง	4,026	29.52	136.38	7	2
TB15	Sai Ngam	ไทรงาม	5,348	41.51	128.84	11	4
Total			92,219	574.93	160.40	180	53

Note: POP ≡ Population; VIL ≡ Village; SCH ≡ School.

Table A1.2 General data for Nakhon Chai Si District (listed by tambon).

Code	Official name		POP (2007)	Area (km^2)	POP density	Number of	
	English	Thai				VIL	SCH
TN1	Bang Kaeo	บางแก้ว	3,564	10.78	330.61	4	1
TN2	Bang Kaeo Fa	บางแก้วฟ้า	3,006	6.71	447.99	5	1
TN3	Bang Krabao	บางกระเบา	4,891	8.31	588.57	3	1
TN4	Bang Phra	บางพระ	2,667	7.39	360.89	4	1
TN5	Bang Rakam	บางระกำ	9,151	8.17	1120.07	4	1
TN6	Don Faek	ดอนแฝก	2,839	2.95	962.37	4	1
TN7	Huai Phlu	ห้วยพลู	4,280	3.14	1363.06	5	2
TN8	Khok Phra Chedi	โคกพระเจดีย์	4,487	13.14	341.48	5	2
TN9	Khun Kaeo	ขุนแก้ว	6,787	19.15	354.41	4	3
TN10	Laem Bua	แหลมบัว	6,841	6.60	1036.51	8	8
TN11	Lan Tak Fa	ลานตากฟ้า	6,868	8.79	781.34	5	2
TN12	Nakhon Chai Si	นครชัยศรี	10,986	3.14	1278.03	3	2
TN13	Ngio Rai	งิ้วราย	2,868	21.81	131.50	4	1
TN14	Phaniat	พะเนียด	3,756	10.53	356.70	4	1
TN15	Tha Krachap	ท่ากระชับ	3,877	23.98	161.68	4	2
TN16	Tha Phraya	ท่าพระยา	3,502	11.51	304.26	5	2
TN17	Tha Tamnak	ท่าตำหนัก	7,182	12.51	574.10	4	1
TN18	Thaiyawat	ไทยาวาส	2,911	24.28	119.89	4	1
TN19	Sampathuan	สัมปทวน	3,831	6.18	619.90	6	2
TN20	Sisa Thong	ศีรษะทอง	6,908	6.07	1138.06	5	2
TN21	Si Maha Pho	ศรีมหาโพธิ์	3,775	6.04	625.00	5	1
TN22	Wat Khae	วัดแค	2,584	17.72	145.82	4	2
TN23	Wat Lamut	วัดละมุด	5,124	8.61	595.12	5	3
TN24	Wat Samrong	วัดสำโรง	1,840	7.37	249.66	4	1
	Total		110,066	265.55	405.02	108	40

Table A1.3 General data for Phutthamonthon District (listed by tambon).

Code	Official name		POP (2007)	Area (km^2)	POP density	Number of	
	English	Thai				VIL	SCH
TP1	Khlong Yong	คลองโยง	7,437	25.25	294.53	8	3
TP2	Maha Sawat	มหาสวัสดิ์	6,257	16.93	369.58	4	2
TP3	Sala Ya	ศาลายา	16,034	29.85	537.15	6	5
Total			29,728	72.03	412.72	18	10

Table A1.4 General data for Sam Phran District (listed by tambon).

Code	Official name		POP (2007)	Area (km^2)	POP density	Number of	
	English	Thai				VIL	SCH
TS1	Ban Mai	บ้านใหม่	8,977	19.36	463.69	5	2
TS2	Bang Chang	บางช้าง	7,531	18.01	626.03	11	4
TS3	Bang Krathuek	บางกระทึก	9,325	14.59	639.14	8	2
TS4	Bang Toei	บางเตย	3,953	8.70	293.68	7	1
TS5	Hom Kret	หอมเกร็ด	7,863	11.52	903.79	6	2
TS6	Khlong Chinda	คลองจินดา	10232	19.60	522.04	14	6
TS7	Khlong Mai	คลองใหม่	9,778	13.46	623.99	7	3
TS8	Krathum Lom	กระทุ่มล้ม	16,106	13.35	1740.65	9	2
TS9	Om Yai	อ้อมใหญ่	15,399	15.67	418.11	8	2
TS10	Rai Khing	ไร่ขิง	21,955	12.03	1644.56	14	4
TS11	Sam Phran	สามพราน	11,491	9.25	966.44	9	2
TS12	Song Khanong	ทรงคนอง	4,082	11.46	354.34	6	1
TS13	Talat Chinda	ตลาดจินดา	7,671	36.83	391.38	11	4
TS14	Tha Kham	ท่าข้าม	9,712	5.57	847.47	6	1
TS15	Tha Talat	ท่าตลาด	14,590	11.89	2691.88	10	2
TS16	Yai Cha	ยายชา	8,201	5.42	455.36	6	2
Total			167,825	226.69	740.33	137	40

APPENDIX B

GENERAL INFORMATION OF THE STUDIED SCHOOLS

Table B1 School data for Bang Len District (2007).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SB1	Ban Phai Cork Wua	บ้านไผ่ดอกวัว	TB1	P	108	S
SB2	Wat Kasem Suriyumnai	วัดเกษมสุริยัมนาจ	TB1	P	198	M
SB3	Ban Bang Len	บ้านบางเลน	TB1	P	583	M
SB4	Ban Pratunam Pra Pimon	บ้านประตูน้ำพระพิมล	TB1	P/LS	388	M
SB5	Bang Len Wittaya	บางเลนวิทยา	TB1	LS/US	1180	L
SB6	Ban Lad Luang.	บ้านลาดหลวง	TB2	P	32	S
SB7	Ban Nong Mamuang	บ้านหนองมะม่วง	TB2	P	74	S
SB8	Wat Lutti Wanaram	วัดลัฏฐิวนาราม	TB2	P	87	S
SB9	Wat Bang Noi Nai	วัดบางน้อยใน	TB2	P	100	S
SB10	Wat Ratsamakkhee	วัดราษฎร์สามัคคี	TB2	P	120	S
SB11	Wat Bang Luang	วัดบางหลวง	TB2	P	419	M
SB12	Bangluang Wittaya.	บางหลวงวิทยา	TB2	LS/US	274	M
SB13	Ban Rang Pla mor	บ้านรางปลาหมอ	TB3	P	108	S
SB14	Ban Klong Pra MorPiSai	บ้านคลองพระมอพิสัย	TB3	P	61	S
SB15	Ban Rang Krg Tum	บ้านรางกระทุ่ม	TB3	P	96	S
SB16	Wat Rang kamyard	วัดรางกำหยาด	TB3	P	193	M
SB17	Talad Rang Kra Tum	ตลาดรางกระทุ่ม	TB3	P	310	M
SB18	Wat Beung Lardsawai	วัดบึงลาดสวาย	TB3	P/LS	287	M
SB19	Wat Koh Rat	วัดเกาะแรต	TB4	P	202	M
SB20	Talad Koh Rat	ตลาดเกาะแรต	TB4	P/LS	139	M

Note: 1. TAM ≡ Tambon; STD ≡ Number of total students.

Table B1 School data for Bang Len District (2007) (Continued).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SB21	Wat Bang Pla	วัดบางปลา	TB4	P/LS	236	M
SB22	Ban Nong Prong.	บ้านหนองปรง	TB5	P	84	S
SB23	Wat Suk Wattanaram	วัดสุขวัฒนาราม	TB5	P	170	M
SB24	Thai Rath Wittaya 4	ไทยรัฐวิทยา 4	TB5	P/LS	148	M
SB25	Wat Pha Sukaram	วัดผาสุการาม	TB6	P	144	M
SB26	Wat Bang Pai Nart	วัดบางไผ่นารถ	TB6	P	154	M
SB27	Wat Borrn Yai	วัดบอนใหญ่	TB7	P	39	S
SB28	Ban Nong Prong Kanchna	บ้านหนองปรงกาญจนา	TB7	P	90	S
SB29	Talad Charoensuk	ตลาดเจริญสุข	TB7	P	149	M
SB30	Wat Bua Wan	วัดบัวหวั่น	TB7	P	200	M
SB31	Bua Pak Tha Witthaya.	บัวปากท่าวิทยา	TB7	LS/US	331	M
SB32	Wat Lad Sakae	วัดลาดสะแก	TB8	P	39	S
SB33	Wat Don Yo	วัดดอนยอ	TB8	P	154	M
SB34	Wat Lan Car	วัดลานคา	TB8	P/LS	369	M
SB35	Ban Phai Luang	บ้านไผ่หลวง	TB9	P	65	S
SB36	Wat Silamul	วัดศิลามูล	TB9	P	241	M
SB37	Ban Khlong Nok Krathung	บ้านคลองนกกระทุง	TB10	P	43	S
SB38	Wat Bang Phasi	วัดบางภาษี	TB10	P	111	S
SB39	Wat Weluwana Ram	วัดเวฬุวนาราม	TB11	P	154	M
SB40	Wat Lam Phaya	วัดลำพญา	TB11	P	261	M
SB41	Sathaphorn Wittaya	สถาพรวิทยา	TB11	LS/US	334	M
SB42	Ban Naraphirom	บ้านนราภิรมย์	TB12	P	63	S
SB43	Wat Phramor phisai	วัดพระมอพิสัย	TB12	P	89	S
SB44	Wat Sawang Arrom	วัดสว่างอารมณ์	TB12	P	108	S

Table B1 School data for Bang Len District (2007) (Continued).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SB45	Wat Naraphirom	วัดนราภิรมย์	TB12	P	364	M
SB46	Wat Bua Pak Tha	วัดบัวปากท่า	TB13	P	107	S
SB47	Wat Nin Phet	วัดนิลเพชร	TB13	P	203	M
SB48	Ban Phai Lom	บ้านไผ่ล้อม	TB14	P	47	S
SB49	Wat Pai Hu Chang	วัดไผ่หูช้าง	TB14	P/LS	296	M
SB50	Wat Phai Jawrakhae	วัดไผ่จรเข้	TB15	P	70	S
SB51	Wat Phai sam Tamlung.	วัดไผ่สามตำลึง	TB15	P	70	S
SB52	Wat Kasettraram	วัดเกษตราราม	TB15	P	169	M
SB53	Wat Pho	วัดโพธิ์	TB15	P/LS	376	M

Table B2 School data for Nakhon Chai Si District (2007).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SN1	Prock Keaw Wittaya	ปรกแก้ววิทยา	TN1	LS/US	193	M
SN2	Wat Bang Phra	วัดบางพระ	TN2	P/LS	324	M
SN3	Wat Tockkata	วัดตุ๊กตา	TN3	P	307	M
SN4	WatKlang	วัดกลาง	TN4	P	126	M
SN5	Wat Bohtakua	วัดบ่อตะกั่ว	TN5	P	154	M
SN6	Ban Khlong Bang Kra Chan	บ้านคลองบางกระจัน	TN6	P	77	S
SN7	Ban Huay Plu	บ้านห้วยพลู	TN7	P	90	S
SN8	Wat Huay Plu	วัดห้วยพลู	TN7	P	338	M
SN9	Wat Kok Prajadee	วัดโคกพระเจดีย์	TN8	P/LS	537	M
SN10	Wat Prachanat	วัดประชานาถ	TN9	P	195	M
SN11	Wat SawangArom	วัดสว่างอารมณ์	TN9	P	221	M

Table B2 School data for Nakhon Chai Si District (2007) (Continued).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SN12	Wat Si Maha Phot	วัดศรีมหาโพธิ	TN9	P/LS	392	M
SN13	Ban Huag Krod	บ้านห้วยกรด	TN10	P	118	S
SN14	WatThong Sai	วัดท้องไทร	TN10	P	132	M
SN15	Wat Thung Noi	วัดทุ่งน้อย	TN10	P	167	M
SN16	WatKok Khema	วัดโคกเขมา	TN10	P	226	M
SN17	Laem Bua Wittaya	แหลมบัววิทยา	TN10	LS/US	408	M
SN18	Wa tPhut Thamrangsi	วัดพุทธธรรมรังษี	TN11	P	96	S
SN19	Wat Lan Takfa	วัดลานตากฟ้า	TN11	P	259	M
SN20	Wat Klang Bang Kaew	วัดกลางบางแก้ว	TN12	P	851	L
SN21	Poem Wittaya	เพิ่มวิทยา	TN12	LS/US	342	M
SN22	Wat Ngyu Rai	วัดงิ้วราย	TN13	P	363	M
SN23	Wat Huay Tako	วัดห้วยตะโก	TN14	P	228	M
SN24	Khlong Tang laung	คลองทางหลวง	TN15	P	226	M
SN25	Wat Sai	วัดไทร	TN15	P	510	M
SN26	Wat Noi	วัดน้อย	TN16	P	164	M
SN27	Ploy Chaturachinda	พลอยจาตุรจินดา	TN16	LS/US	170	M
SN28	Wat TaTum Nak	วัดท่าตำหนัก	TN17	P	408	M
SN29	Wat Thaiyawat	วัดไทยาวาส	TN18	P	111	S
SN30	Wat kok tarn	วัดกกตาล	TN19	P	260	M
SN31	Wat Klang Ku Wiang	วัดกลางครูเวียง	TN19	P	308	M
SN32	Wat Satan Rattanaram	วัดเสถียรรัตนาราม	TN20	P	94	S
SN33	Wat Srisatong	วัดศรีษะทอง	TN20	P/LS	530	M
SN34	Ngyu Rai Bunminest Sarit	งิ้วรายบุญมีรังสฤษดิ์	TN21	LS/US	605	L
SN35	Wat Sampathuan	วัดสัมปทวน	TN22	P	139	M
SN36	Pattanayarn Wittaya	ภัทรญาณวิทยา	TN22	LS/US	1326	L

Table B2 School data for Nakhon Chai Si District (2007) (Continued).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SN37	Ban Larn Laem	บ้านลานแหลม	TN23	P	163	M
SN38	Wat Lamut	วัดละมุด	TN23	P	180	M
SN39	Wat Mai Sukhontharam	วัดใหม่สุคนธาราม	TN23	P	200	M
SN40	Wat Samrong	วัดสำโรง	TN24	P	120	S

Table B3 School data for Phutthamonthon District (2007).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SP1	BoonyaSrisawat.	บุณยศรีสวัสดิ์	TP1	P	477	M
SP2	Ban Khlong Sawang Arrom	บ้านคลองสว่างอารมณ์	TP1	P/LS	105	S
SP3	Wat Makleur	วัดมะเกลือ	TP1	P/LS	550	M
SP4	Ban Khlong Mahasawad	บ้านคลองมหาสวัสดิ์	TP2	P	106	S
SP5	Ban Khlong Yong.	บ้านคลองโยง	TP2	P/LS	248	M
SP6	Wat Suwannaram.	วัดสุวรรณาราม	TP3	P	178	M
SP7	Wat Salawan	วัดสาลวัน	TP3	P	319	M
SP8	PraTumNak Suankularbmaha Mongkon	พระตำหนักสวนกุหลาบมหามงคล	TP3	P	1810	VL
SP9	Rattanakosin Sompotch Bovornnives Salaya.	รัตนโกสินทร์สมโภชบวรนิเวศฯ	TP3	LS/US	1772	VL
SP10	Kanchonapisek Wittayalai	กาญจนาภิเษกวิทยาลัย	TP3	LS/US	2304	VL
SS1	Bang Pradaeng	บ้านบางประแดง	TS1	P	194	M
SS2	Wat Tian Datt	วัดเทียนดัด	TS1	P/LS	566	M
SS3	Ban Bang Muang	บ้านบางม่วง	TS2	P	83	S

Table B4 School data for Sam Phran District (2007).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SS1	Bang Pradaeng	บ้านบางประแดง	TS1	P	194	M
SS2	Wat Tian Datt	วัดเทียนดัด	TS1	P/LS	566	M
SS3	Ban Bang Muang	บ้านบางม่วง	TS2	P	83	S
SS4	Ban Hua Ao.	บ้านหัวอ่าว	TS2	P	96	S
SS5	Wat Choeng Len	วัดเชิงเลน	TS2	P	175	M
SS6	Wat Bang Chang Tai	วัดบางช้างใต้	TS2	P	445	M
SS7	Klong Bang Kratuek	คลองบางกระทึก	TS3	P	274	M
SS8	Wat Don Wai	วัดดอนหวาย	TS3	P/LS	1349	L
SS9	Ban Bang Toei	บ้านบางเตย	TS4	P	170	M
SS10	Ban Hom Kret	บ้านหอมเกร็ด	TS5	P	164	M
SS11	Wat Hom Kret	วัดหอมเกร็ด	TS5	P/LS	737	L
SS12	Ban Pard Mon	บ้านพาดหมอน	TS6	P	53	S
SS13	Ban Chang	บ้านฉาง	TS6	P	84	S
SS14	Ban Klong Chinda	บ้านคลองจินดา	TS6	P	90	S
SS15	Wat Preedaram	วัดปรีดาราม	TS6	P	257	M
SS16	Wat Wang Nam Khao	วัดวังน้ำขาว	TS6	P/LS	371	M
SS17	Pridaram Wittayakhom	ปรีดารามวิทยาคม	TS6	LS/US	332	M
SS18	Wat Bang Chang	วัดบางช้างเหนือ	TS7	P	73	S
SS19	Ban Don Thong	บ้านดอนทอง	TS7	P	101	S
SS20	Ban Khlong Mai	บ้านคลองใหม่	TS7	P	428	M
SS21	Ban Plern Wattana	บ้านเพลินวัฒนา	TS8	P	310	M
SS22	Ban Kratum Lom	บ้านกระทุ่มล้ม	TS8	P/LS	1063	L
SS23	Wat Om Yai	วัดอ้อมใหญ่	TS9	P	311	M
SS24	Ban Khlong Lad Aom	บ้านคลองลัดอ้อมใหญ่	TS9	P	382	M
SS25	Wat Deja Nusorn.	วัดเดชานุสรณ์	TS10	P	117	S

Table B4 School data for Sam Phran District (2007) (Continued).

Code	Official name		TAM	Level	STD	Scale
	English	Thai				
SS26	Wat Tha Pued	วัดท่าพูด	TS10	P/LS	1179	L
SS27	Wat Rai Khing	วัดไร่ขิง	TS10	P	2027	VL
SS28	Wat Rai Khing Wittaya	วัดไร่ขิงวิทยา	TS10	LS/US	2812	VL
SS29	Ban Dong Ket	บ้านดงเกตุ	TS11	P	341	M
SS30	Ban San Phran	บ้านสามพราน	TS11	P	615	L
SS31	Wat Songkanong	วัดทรงคนอง	TS12	P	146	M
SS32	Ban Tak Dad	บ้านตากแดด	TS13	P	55	S
SS33	Luang Poh Cham Upathum	หลวงพ่อแช่มอุปถัมภ์	TS13	P	80	S
SS34	Wat Rat Sattharam	วัดราษฎร์ศรัทธาราม	TS13	P	163	M
SS35	Wat Jinda Ram	วัดจินดาราม	TS13	P/LS	790	L
SS36	Wat Tha Kham.	วัดท่าข้าม	TS14	P	191	M
SS37	Ban Tha Talad	บ้านท่าตลาด	TS15	P	97	S
SS38	Por.Phor.Roh.Rajawittayalai	ภ.ป.ร.ราชวิทยาลัยฯ	TS15	LS/US	1269	L
SS39	Wat Sanphet	วัดสรรเพชญ	TS16	P	522	M
SS40	San Phran Wittaya	สามพรานวิทยา	TS16	LS/US	1170	L

APPENDIX C

DATA FOR THE IDEALIZED METHOD

Table C1.1 Information of the 50 selected sites at P level (idealized).

Bang Len (23)					Bang Len (23)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB3	P	L	บ้านบางเลน	TB1	SB30	P	M	วัดบัวหวั่น	TB7
SB6	P	S	บ้านลาดหลวง	TB2	SB34	P/LS	M	วัดลานคา	TB8
SB7	P	S	บ้านหนองมะม่วง	TB2	SB36	P	M	วัดศิลามูล	TB9
SB11	P	L	วัดบางหลวง	TB2	SB39	P	M	วัดเวฬุวนาราม	TB11
SB16	P	M	วัดรางกำหยาด	TB3	SB40	P	M	วัดลำพญา	TB11
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB44	P	M	วัดสว่างอารมณ์	TB12
SB20	P/LS	M	ตลาดเกาะแรต	TB4	SB45	P	M	วัดนราภิรมย์	TB12
SB21	P/LS	M	วัดบางปลา	TB4	SB47	P	M	วัดนิลเพชร	TB13
SB23	P	M	วัดสุขวัฒนาราม	TB5	SB49	P/LS	M	วัดไผ่หูช้าง	TB14
SB24	P/LS	M	ไทยรัฐวิทยา 4	TB5	SB52	P	M	วัดเกษตราราม	TB15
SB26	P	M	วัดบางไผ่นารถ	TB6	SB53	P/LS	M	วัดโพธิ์	TB15
SB29	P	M	ตลาดเจริญสุข	TB7					
Nakhon Chai Si (12)					**Nakhon Chai Si (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	
SN2	P/LS	M	วัดบางพระ	TN2	SN14	P	M	วัดท้องไทร	TN10
SN5	P	M	วัดบ่อตะกั่ว	TN5	SN20	P	L	วัดกลางบางแก้ว	TN12
SN8	P/LS	L	วัดห้วยพลู	TN7	SN22	P	L	วัดงิ้วราย	TN13
SN9	P/LS	L	วัดโคกพระเจดีย์	TN8	SN25	P	L	วัดไทร	TN15
SN10	P	M	วัดประชานาถ	TN9	SN30	P	L	วัดกกตาล	TN19
SN12	P/LS	L	วัดศรีมหาโพธิ	TN9	SN33	P/LS	M	วัดศรียะทอง	TN20

Table C1.1 Information of the 50 selected sites at P level (idealized) (Continued).

Phutthamonthon (4)					Phutthamonthon (4)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	M	วัดมะเกลือ	TP1	SP6	P	M	วัดสุวรรณาราม	TP3
SP5	P/LS	L	บ้านคลองโยง	TP2	SP8	P	VL	พระตำหนักฯ	TP3
Sam Phran (11)					**Sam Phran (11)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	VL	วัดเทียนดัด	TS1	SS26	P/LS	L	วัดท่าพูด	TS10
SS8	P/LS	VL	วัดดอนหวาย	TS3	SS27	P	VL	วัดไร่ขิง	TS10
SS11	P/LS	L	วัดหอมเกร็ด	TS5	SS30	P	VL	บ้านสามพราน	TS11
SS15	P	M	วัดปรีดาราม	TS6	SS35	P/LS	L	วัดจินดาราม	TS13
SS16	P/LS	M	วัดวังน้ำขาว	TS6	SS39	P	M	วัดสรรเพชญ	TS16
SS22	P/LS	VL	บ้านกระทุ่มล้ม	TS8					

Note: TAM ≡ Tambon, Scale ≡ Resulted school scale in the clustering scenario.

Table C1.2 Data of the 50 selected sites at LS level (idealized).

Bang Len (20)					Bang Len (20)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB4	P/LS	M	บ้านประตูน้ำพระพิมล	TB1	SB30	P	M	วัดบัวหวั่น	SB30
SB5	LS/US	L	บางเลนวิทยา	TB1	SB31	P/US	M	บัวปากท่าวิทยา	SB31
SB6	P	S	บ้านลาดหลวง	TB2	SB34	P/LS	M	วัดลานคา	SB34
SB7	P	S	บ้านหนองมะม่วง	TB2	SB40	P	M	วัดลำพญา	TB11
SB12	LS/US	M	บางหลวงวิทยา	TB2	SB41	LS/US	M	สถาพรวิทยา	SB41
SB16	P	M	วัดรางกำหยาด	TB3	SB44	P	S	วัดสว่างอารมณ์	TB12
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB45	P	M	วัดนราภิรมย์	TB12
SB20	P/LS	S	ตลาดเกาะแรต	TB4	SB49	P/LS	S	วัดไผ่หูช้าง	TB14
SB21	P/LS	S	วัดบางปลา	TB4	SB52	P	M	วัดเกษตราราม	TB15
SB24	P/LS	S	ไทยรัฐวิทยา 4	TB5	SB53	P/LS	M	วัดโพธิ์	TB15

Table C1.2 Data of the 50 selected sites at LS level (idealized) (Continued).

Nakhon Chai Si (12)					Nakhon Chai Si (12)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN1	LS/US	M	ปรกแก้ววิทยา	TN1	SN19	P	M	วัดลานตากฟ้า	TN11
SN2	P/LS	M	วัดบางพระ	TN2	SN21	LS/US	M	เพิ่มวิทยา	TN12
SN8	P/LS	S	วัดห้วยพลู	TN7	SN27	LS/US	M	พลอยจาตุรจินดา	TN16
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN33	P/LS	M	วัดศรีษะทอง	TN20
SN12	P/LS	M	วัดศรีมหาโพธิ	TN9	SN34	LS/US	M	งิ้วรายบุญมี รังสฤษดิ์	TN21
SN17	LS/US	M	แหลมบัววิทยา	TN10	SN36	LS/US	L	ภัทรญาณวิทยา	TN22
Phutthamonthon (6)					**Phutthamonthon (6)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP2	P/LS	S	บ้านคลองสว่าง อารมณ์	TP1	SP5	P/LS	S	บ้านคลองโยง	TP2
SP3	P/LS	M	วัดมะเกลือ	TP1	SP9	LS/US	L	รัตนโกสินทร์	TP3
SP4	P	-	บ้านคลองมหาสวัสดิ์	TP2	SP10	LS/US	L	กาญจนาภิเษกฯ	TP3
Sam Phran (12)					**Sam Phran (12)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	M	วัดเทียนดัด	TS1	SS22	P/LS	M	บ้านกระทุ่มล้ม	TS8
SS6	P	M	วัดบางช้างใต้	TS2	SS26	P/LS	M	วัดท่าพูด	TS10
SS8	P/LS	M	วัดดอนหวาย	TS3	SS28	LS/US	L	วัดไร่ขิงวิทยา	TS10
SS11	P/LS	M	วัดหอมเกร็ด	TS5	SS35	P/LS	M	วัดจินดาราม	TS13
SS16	P/LS	M	วัดวังน้ำขาว	TS6	SS38	LS/US	L	ภ.ป.ร.ราช วิทยาลัยฯ	TS15
SS17	LS/US	M	ปรีดารามวิทยาคม	TS6	SS40	LS/US	L	สามพรานวิทยา	TS16

Table C1.3 Data of the 18 selected sites at US level (idealized).

Bang Len (5)					Bang Len (5)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	M	บางเลนวิทยา	TB1	SB31	LS/US	S	บัวปากท่าวิทยา	TB7
SB12	LS/US	S	บางหลวงวิทยา	TB2	SB41	LS/US	S	สถาพรวิทยา	TB11
SB18	P/LS	S	วัดบึงลาดสวาย	TB3					
Nakhon Chai Si (6)					**Nakhon Chai Si (6)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN2	P/LS	M	วัดบางพระ	TN2	SN21	LS/US	S	เพิ่มวิทยา	TN12
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN34	LS/US	M	งิ้วรายบุญมี รังสฤษดิ์	TN21
SN17	LS/US	S	แหลมบัววิทยา	TN10	SN36	LS/US	M	ภัทรญาณวิทยา	TN22
Phutthamonthon (2)					**Phutthamonthon (2)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP9	LS/US	M	รัตนโกสินทร์ สมโภชฯ	TP3	SP10	LS/US	L	กาญจนาภิเษกฯ	TP3
Sam Phran (5)					**Sam Phran (5)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	LS/US	M	วัดเทียนดัด	TS1	SS38	LS/US	M	ภ.ป.ร.ราชวิทยาลัยฯ	TS15
SS17	LS/US	S	ปรีดาราม วิทยาคม	TS6	SS40	LS/US	M	สามพรานวิทยา	TS16
SS28	LS/US	L	วัดไร่ขิงวิทยา	TS10	-	-	-	-	-

มหาวิทยาลัยเทคโนโลยีสุรนารี

APPENDIX D

DATA FOR THE P-MEDIAN AND GRAVITY P-MEDIAN MODELS

Table D1.1 Information of the 75 potential sites at P level (p-median).

Bang Len (30)					Bang Len (30)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB2	P	M	วัดเกษมสุริยัมนาจ	TB1	SB36	P	M	วัดศิลามูล	TB9
SB3	P	M	บ้านบางเลน	TB1	SB39	P	M	วัดเวฬุวนาราม	TB11
SB4	P/LS	M	บ้านประตูน้ำพระพิมล	TB1	SB40	P	L	วัดลำพญา	TB11
SB11	P	L	วัดบางหลวง	TB2	SB44	P	M	วัดสว่างอารมณ์	TB12
SB14	P	M	บ้านคลองพระมอพิสัย	TB3	SB46	P	M	วัดบัวปากท่า	TB13
SB16	P	M	วัดรางกำหยาด	TB3	SB47	P	L	วัดนิลเพชร	TB13
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB48	P	S	บ้านไผ่ล้อม	TB14
SB19	P	M	วัดเกาะแรต	TB4	SB49	P/LS	M	วัดไผ่หูช้าง	TB14
SB20	P/LS	M	ตลาดเกาะแรต	TB4	SB52	P	M	วัดเกษตราราม	TB15
SB21	P/LS	M	วัดบางปลา	TB4	SB53	P/LS	M	วัดโพธิ์	TB15
SB23	P	M	วัดสุขวัฒนาราม	TB5	SB17	P	M	ตลาดรางกระทุ่ม	TB3
SB25	P	M	วัดผาสุการาม	TB6	SB24	P/LS	M	ไทยรัฐวิทยา 4	TB5
SB26	P	M	วัดบางไผ่นารถ	TB6	SB29	P	M	ตลาดเจริญสุข	TB7
SB30	P	M	วัดบัวหวั่น	TB7	SB33	P	M	วัดดอนยอ	TB8
SB34	P/LS	M	วัดลานคา	TB8	SB45	P	M	วัดนราภิรมย์	TB12
SN8	P/LS	M	วัดห้วยพลู	TN7	SN2	P/LS	M	วัดบางพระ	TN2
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	SN4	P	M	วัดกลาง	TN4
SN10	P	L	วัดประชานาถ	TN9	SN5	P	M	วัดบ่อตะกั่ว	TN5
SN12	P/LS	L	วัดศรีมหาโพธิ	TN9	SN11	P	M	วัดสว่างอารมณ์	TN9

Table D1.1 Information of the 75 potential sites at P level (p-median) (Continued).

Nakhon Chai Si (24)					Nakhon Chai Si (24)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN19	P	M	วัดลานตากฟ้า	TN11	SN14	P	M	วัดท้องไทร	TN10
SN20	P	L	วัดกลางบางแก้ว	TN12	SN16	P	M	วัดโคกเขมา	TN10
SN22	P	M	วัดงิ้วราย	TN13	SN23	P	M	วัดห้วยตะโก	TN14
SN25	P	L	วัดไทร	TN15	SN24	P	M	คลองทางหลวง	TN15
SN26	P	L	วัดน้อย	TN16	SN31	P	M	วัดกลางครูเวียง	TN19
SN28	P	M	วัดท่าตำหนัก	TN17	SN33	P/LS	M	วัดศรีษะทอง	TN20
SN30	P	L	วัดกกตาล	TN19	SN35	P	M	วัดสัมปทวน	TN22
SN39	P	L	วัดใหม่สุคนธาราม	TN23	SN37	P	M	บ้านลานแหลม	TN23
Phutthamonthon (5)					**Phutthamonthon (5)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	L	วัดมะเกลือ	TP1	SP1	P	M	บุณยศรีสวัสดิ์	TP1
SP5	P/LS	L	บ้านคลองโยง	TP2	SP6	P	M	วัดสุวรรณาราม	TP3
SP8	P	VL	พระตำหนักฯ	TP3					
Sam Phran (16)					**Sam Phran (16)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS2	P/LS	L	วัดเทียนดัด	TS1	SS35	P/LS	L	วัดจินดาราม	TS13
SS6	P	L	วัดบางช้างใต้	TS2	SS39	P	L	วัดสรรเพชญ	TS16
SS8	P/LS	VL	วัดดอนหวาย	TS3	SS9	P	M	บ้านบางเตย	TS4
SS11	P/LS	L	วัดหอมเกร็ด	TS5	SS15	P	M	วัดปรีดาราม	TS6
SS16	P/LS	L	วัดวังน้ำขาว	TS6	SS20	P	M	บ้านคลองใหม่	TS7
SS22	P/LS	VL	บ้านกระทุ่มล้ม	TS8	SS26	P/LS	L	วัดท่าพูด	TS10
SS24	P	L	บ้านคลองลัดฯ	TS9	SS31	P	M	วัดทรงคนอง	TS12
SS27	P	VL	วัดไร่ขิง	TS10	SS40	P	L	บ้านสามพราน	TS11

Note: TAM ≡ Tambon, Scale ≡ Resulted school scale in the p-median scenario.

Table D1.2 Information of the 75 potential sites at LS level (p-median).

Bang Len (30)					Bang Len (30)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB2	P	M	วัดเกษมสุริยัมนาจ	TB1	SB34	P/LS	M	วัดลานคา	TB8
SB5	LS/US	L	บางเลนวิทยา	TB1	SB36	P	M	วัดศิลามูล	TB9
SB12	LS/US	M	บางหลวงวิทยา	TB2	SB40	P	M	วัดลำพญา	TB11
SB16	P	M	วัดรางกำหยาด	TB3	SB41	LS/US	M	สถาพรวิทยา	TB11
SB17	P	M	ตลาดรางกระทุ่ม	TB3	SB44	P	S	วัดสว่างอารมณ์	TB12
SB18	P/LS	M	วัดบึงลาดสวาย	TB3	SB46	P	S	วัดบัวปากท่า	TB13
SB19	P	M	วัดเกาะแรต	TB4	SB48	P	S	บ้านไผ่ล้อม	TB14
SB20	P/LS	S	ตลาดเกาะแรต	TB4	SB49	P/LS	S	วัดไผ่หูช้าง	TB14
SB21	P/LS	S	วัดบางปลา	TB4	SB52	P	M	วัดเกษตราราม	TB15
SB23	P	S	วัดสุขวัฒนาราม	TB5	SB53	P/LS	M	วัดโพธิ์	TB15
SB25	P	M	วัดผาสุการาม	TB6	SB4	P/LS	M	บ้านประตูน้ำพระพิมล	TB1
SB26	P	M	วัดบางไผ่นารถ	TB6	SB14	P	M	บ้านคลองพระมอพิสัย	TB3
SB29	P	M	ตลาดเจริญสุข	TB7	SB24	P/LS	S	ไทยรัฐวิทยา 4	TB5
SB30	P	M	วัดบัวหวั่น	TB7	SB33	P	M	วัดดอนยอ	TB8
SB31	LS/US	M	บัวปากท่าวิทยา	TB7	SB45	P	M	วัดนราภิรมย์	TB12
Nakhon Chai Si (24)					**Nakhon Chai Si (24)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN1	L	M	ปรกแก้ววิทยา	TN1	SN34	LS/US	M	จิ้วรายบุญมีรังสฤษดิ์	TN21
SN8	P/LS	M	วัดห้วยพลู	TN7	SN36	LS/US	L	ภัทรญาณวิทยา	TN22
SN9	P/LS	M	วัดโคกพระเจดีย์	TN8	TN2	-	-	วัดบางพระ	TN2
SN12	P/LS	M	วัดศรีมหาโพธิ	TN9	TN3	-	-	ต.บางกระเบา	TN3
SN17	L	M	แหลมบัววิทยา	TN10	TN4	-	-	ต.บางพระ	TN4
SN21	L	M	เพิ่มวิทยา	TN12	TN5	-	-	ต.บางระกำ	TN5
SN27	LS/US	M	พลอยจาตุรจินดา	TN16	TN6	-	-	ต.ดอนแฝก	TN6
SN33	P/LS	L	วัดศรีษะทอง	TN20	TN11	-	-	ต.ลานตากฟ้า	TN11

Table D1.2 Information of the 75 potential sites at LS level (p-median) (Continued).

Nakhon Chai Si (24)					Nakhon Chai Si (24)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TN14	-	-	ต.พะเนียด	TN14	TN13	-	-	ต.งิ้วราย	TN13
TN17	-	-	ต.ท่าตำหนัก	TN17	TN15	-	-	ต.ท่ากระชับ	TN15
TN18	-	M	ต.ไทยาวาส	TN18	TN19	-	-	ต.สัมปทวน	TN19
TN24	-	-	ต.วัดสำโรง	TN24	TN23	-	-	ต.วัดละมุด	TN23
Phutthamonthon (5)					**Phutthamonthon (5)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP3	P/LS	M	วัดมะเกลือ	TP1	SP2	P/LS	S	บ้านคลองสว่างอารมณ์	TP1
SP5	P/LS	S	บ้านคลองโยง	TP2	SP9	LS/US	M	รัตนโกสินทร์ฯ	TP3
SP10	LS/US	VL	กาญจนาภิเษกฯ	TP3	-	-	-	-	-
Sam Phran (16)					**Sam Phran (16)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS11	P/LS	L	วัดหอมเกร็ด	TS5	TS11	-	-	ต.สามพราน	TS11
SS17	LS/US	M	ปรีดาราม วิทยาคม	TS6	TS12	-	-	ต.ทรงคนอง	TS12
SS22	P/LS	M	บ้านกระทุ่มล้ม	TS8	SS2	P/LS	M	วัดเทียนดัด	TS1
SS35	P/LS	M	วัดจินดาราม	TS13	SS8	P/LS	M	วัดดอนหวาย	TS3
SS40	LS/US	L	สามพรานวิทยา	TS16	SS16	P/LS	M	วัดวังน้ำขาว	TS6
TS2	-	-	ต.บางช้าง	TS2	SS26	P/LS	M	วัดท่าพูด	TS10
TS7	-	-	ต.คลองใหม่	TS7	SS28	LS/US	VL	วัดไร่ขิงวิทยา	TS10
TS9	-	-	ต.อ้อมใหญ่	TS9	SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15

Table D1.3 Information of the 58 potential sites at US level (p-median).

Bang Len (15)					Bang Len (15)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	L	บางเลนวิทยา	TB1	TB15	-	-	ต.ไทรงาม	TB15
SB31	LS/US	S	บัวปากท่าวิทยา	TB7	SB12	LS/US	S	บางหลวงวิทยา	TB2
SB41	LS/US	S	สถาพรวิทยา	TB11	TB3			ต.บางภาษี	TB3
TB4	-	-	ต.บางปลา	TB4	TB8			ต.ดอนตูม	TB8
TB5	-	-	ต.บางระกำ	TB5	TB10			ต.คลองนกกระทุง	TB10
TB6	-	-	ต.บางไทรป่า	TB6	TB12			ต.นราภิรมย์	TB12
TB9	-	M	ต.หินมูล	TB9	TB14			ต.ไผ่หูช้าง	TB14
TB13	-	-	ต.นิลเพชร	TB13	-	-	-	-	-
Nakhon Chai Si (24)					**Nakhon Chai Si (24)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SN17	LS/US	S	แหลมบัว	TN10	SN27	LS/US	S	พลอยจาตุรจินดา	SN27
SN21	LS/US	M	เพิ่มวิทยา	TN12	TN7	-	M	ต.ห้วยพลู	TN7
TN1	-	-	ต.บางแก้ว	TN1	TN14	-	-	ต.พะเนียด	TN14
TN2	-	-	ต.บางแก้วฟ้า	TN2	TN15	-	-	ต.ท่ากระชับ	TN15
TN3	-	-	ต.บางกระเบา	TN3	TN17	-	-	ต.ท่าตำหนัก	TN17
TN4	-	-	ต.บางพระ	TN4	TN18	-	-	ต.ไทยาวาส	TN18
TN5	-	-	ต.บางระกำ	TN5	TN19	-	-	ต.สัมปทวน	TN19
TN6	-	-	ต.ดอนแฝก	TN6	TN20	-	-	ต.ศิรษะทอง	TN20
TN8	-	-	ต.โคกพระเจดีย์	TN8	TN21	-	-	ต.ศรีมหาโพธิ์	TN21
TN9	-	-	ต.ขุนแก้ว	TN9	TN22	-	-	ต.วัดแค	TN22
TN11	-	-	ต.ลานตากฟ้า	TN11	TN23	-	-	ต.วัดละมุด	TN23
TN13	-	-	ต.งิ้วราย	TN13	TN24	-	-	ต.วัดสำโรง	TN24

Table D1.3 Information of the 58 potential sites at US level (p-median) (Continued).

Phutthamonthon (3)					Phutthamonthon (3)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SP9	LS/US	L	รัตนโกสินทร์สมโภชบวรนิ	TP3	SP3	P/LS	M	วัดมะเกลือ	TP1
SP10	LS/US	L	กาญจนาภิเษกฯ	TP3					
Sam Phran (16)					**Sam Phran (16)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS17	LS/US	S	ปรีดารามวิทยาคม	TS6	TS1	-	-	ต.บ้านใหม่	TS1
SS38	LS/US	L	ภ.ป.ร.ราชวิทยาลัยฯ	TS15	TS3	-	-	ต.บางกระทึก	TS3
SS28	LS/US	L	ไร่ขิงวิทยา	TS10	TS8	-	-	ต.กระทุ่มล้ม	TS8
SS40	LS/US	L	สามพรานวิทยา	TS16	TS9	-	-	ต.อ้อมใหญ่	TS9
TS2	-	-	ต.บางช้าง	TS2	TS11	-	-	ต.สามพราน	TS11
TS4	-	-	ต.บางเตย	TS4	TS12	-	-	ต.ทรงคนอง	TS12
TS5	-	-	ต.หอมเกร็ด	TS5	TS13	-	-	ต.ตลาดจินดา	TS13
TS7	-	-	ต.คลองใหม่	TS7	TS14	-	-	ต.ท่าข้าม	TS14

Table D1.4 Information of the 59 potential sites at US level (gravity p-median).

Bang Len (15)					Bang Len (15)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SB5	LS/US	M	บางเลนวิทยา	TB1	TB9	-	-	ต.หินมูล	TB9
SB12	LS/US	S	บางหลวงวิทยา	TB2	TB8	-	-	ต.ดอนตูม	TB8
SB31	LS/US	S	บัวปากท่าวิทยา	TB7	TB10	-	-	ต.คลองนกกระทุง	TB10
SB41	LS/US	S	สถาพรวิทยา	TB11	TB12	-	-	ต.นราภิรมย์	TB12
TB3	-	-	ต.บางภาษี	TB3	TB13	-	-	ต.นิลเพชร	TB13
TB4	-	-	ต.บางปลา	TB4	TB14	-	-	ต.ไผ่หูช้าง	TB14
TB5	-	-	ต.บางระกำ	TB5	TB15	-	-	ต.ไทรงาม	TB15
TB6	-	-	ต.บางไทรป่า	TB6	TB10	-	-	ต.คลองนกกระทุง	TB10

Table D1.4 Information of the 59 potential sites at US level (gravity p-median) (Continued).

Nakhon Chai Si (24)					Nakhon Chai Si (24)				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TN2	-	-	ต.บางแก้วฟ้า	TN2	SN36	LS/US	M	ภัทรญาณวิทยา	TN22
TN3	-	-	ต.บางกระเบา	TN3	TN17	-	-	ต.ท่าตำหนัก	TN17
TN4	-	-	ต.บางพระ	TN4	TN18	-	-	ต.ไทยาวาส	TN18
TN6	-	-	ต.ดอนแฝก	TN6	TN19	-	-	ต.สัมปทวน	TN19
TN8	-	-	ต.โคกพระเจดีย์	TN8	TN20	-	-	ต.ศีรษะทอง	TN20
TN9	-	-	ต.ขุนแก้ว	TN9	TN21	-	-	ต.ศรีมหาโพธิ์	TN21
TN11	-	-	ต.ลานตากฟ้า	TN11	TN23	-	-	ต.วัดละมุด	TN23
TN15	-	-	ต.ท่ากระชับ	TN15	TN24	-	-	ต.วัดสำโรง	TN24
Phutthamonthon (4)					**Phutthamonthon (4)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
TP2	TP1	TP1	ต.มหาสวัสดิ์	TP2	SP9	LS/US	M	รัตนโกสินทร์ฯ	TP3
TP1	TP1	TP1	ต.คลองโยง	TP1	SP10	LS/US	L	กาญจนาภิเษกฯ	TP3
Sam Phran (16)					**Sam Phran (16)**				
Code	**Level**	**Scale**	**Official name**	**TAM**	**Code**	**Level**	**Scale**	**Official name**	**TAM**
SS17	LS/US	S	ปรีดาราม วิทยาคม	TS6	TS3	-	-	ต.บางกระทึก	TS3
SS38	LS/US	L	ภ.ป.ร.ราช วิทยาลัยฯ	TS15	TS9	-	-	ต.อ้อมใหญ่	TS9
SS28	LS/US	L	ไร่ขิงวิทยา	TS10	TS7	-	-	ต.คลองใหม่	TS7
SS40	LS/US	L	สามพรานวิทยา	TS16	TS8	-	-	ต.กระทุ่มล้ม	TS8
TS1	-	-	ต.บ้านใหม่	TS1	TS11	-	-	ต.สามพราน	TS11
TS2	-	-	ต.บางช้าง	TS2	TS12	-	-	ต.ทรงคนอง	TS12
TS4	-	-	ต.บางเตย	TS4	TS13	-	-	ต.ตลาดจินดา	TS13
TS5	-	-	ต.หอมเกร็ด	TS5	TS14	-	-	ต.ท่าข้าม	TS14

CURRICULUM VITAE

Miss Sirirat Phongpippattanapan was born on 18th May 1972 in Phattalung Province, Southern Thailand. She received the B.Sc. degree in Geography from the Department of Geography, Faculty of Humanities and Social Sciences, Prince of Songkla University (Pattani Campus) in 1992 and Master Degree in Geography from Srinakharinwirot University in 1998. During 1998-1999, she worked as a scientist (GIS technician) at Centre for Industrial and Environmental Training (CIET), Walailak University and later (from 2000-present) became a researcher for Education Quality Assurance at Faculty of Social Sciences, Mahidol Wittayanusorn School. In 2005, she had been granted a scholarship from the School to pursue her Ph.D. study at the School of Remote Sensing, Institute of Science, Suranaree University of Technology.

มหาวิทยาลัยเทคโนโลยีสุรนารี