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# Solar powered light emitting diode distribution in developing countries: An assessment of potential distribution sites in rural Cambodia using network analyses

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## ABSTRACT

The objective of this research is to use geographic information systems and spatial analyses to create a template for distributing lighting, particularly light emitting diodes, in developing countries. Approximately 1.6 billion people do not have access to traditional electrical systems; therefore, a significant number of people do not have access to safe, efficient, and inexpensive lighting technologies. This research addresses the need for lighting in one developing country. As an introductory case study area for the distribution of lighting products, Cambodia has a population that is considerable, rural, and without electricity. In addition, a significant percentage of Cambodia's population will not have access to grid-quality electricity by 2030. To help alleviate this lighting deficiency, eliminate inappropriate distribution areas, and create a list of potential locations, the authors use geographic information system techniques to address four site-specific characteristics (grid electricity access, water inundation potential, hazardous landmine locations, and extreme poverty levels). To select among potential locations, the authors combine spatial analyses, service area delineations, and origin-destination cost matrices into a heuristic method for determining one location. These analyses identify the commune of Kantreang as the most appropriate location for lighting distribution.

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## 1. Introduction

The objective of this article is to use a series of spatial analytical procedures to create a template for the investigation of lighting distribution locations in developing countries. Specifically, this research facilitates locating a site that an organization—Light Up the World (LUTW) Foundation—can target to achieve its mission. Its mission is to provide safe, affordable, sustainable, and efficient lighting to the 1.6 billion people who do not have access to traditional, grid-quality electrical systems [1]. This organization provides solar powered, solid-state light emitting diode (LED) technology to residences and businesses without access to grid electricity. In a decade, the organization has illuminated the lives of more than 900,000 individuals in over 50 countries [2]. To date, LUTW projects are continuing in Ghana, South Africa, Papua New Guinea, Tibet, India, Pakistan, Nepal, Sri Lanka, Afghanistan, Costa Rica, Ecuador, Mexico, Peru, the Dominican Republic, and the Philippines. For this analysis, the authors focus on one country,

Cambodia, which has a rural-majority population without access to grid electricity. Cambodia serves as a template for lighting distribution in other developing countries.

A review of international human rights law suggests that access to electricity and lighting is a basic human right [3]. Providing electricity to a rural population alleviates extreme poverty [4], expands economic development [5], and elevates literacy levels [6]. Electricity also reduces environmental damage, especially when cleaner or renewable sources of energy replace individual fossil fuel burning [1]. However, the provision of electricity over an extensive geographical area to the rural poor requires a large capital expenditure that is often beyond the capabilities of most developing countries' governments. Given the combination of a laudable objective of improving socio-economic conditions in a developing country with cost constraints, it is reasonable to presume that the quantitative methods of operations research and management science can ultimately encourage these social benefits.

The field of location science addresses and models the general problem of providing a service to a population in a geographic region, and scientists frequently apply these service models in social scientific contexts [7]. Three proven models with a range of useful applications include the p-median model, the maximal

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covering location model, and the maximal dispersion model. The p-median model [8,9] minimizes the demand weighted distance (or cost) to serve a dispersed population. The maximal covering location model serves the greatest population within a specified covering distance [10], and the maximal dispersion model spreads facilities among a population [11,12]. Although this is not the appropriate forum to review the literature surrounding these models, they employ a variety of spatial representations [13] to solve social problems that require the provision of services to a rural, dispersed population [14–16].

While a range of solutions exists for these models [17,18], the applications can be combinatorially complex and difficult to solve in some instances. Moreover, the tools for solving these problems optimally are neither widely available, nor are the methods commonly employed by organizations operating under extreme budget and time constraints. Because of these limitations and the objective of locating a single distribution site, these models may not be necessary or prudent. While there is research into the optimal location of facilities that provide grid-quality electricity [19], these methods generally use a linear programming approach to site large, capital intensive, regional energy facilities. This approach is simply too complex and expensive for a local, non-capital intensive facility to distribute LED lighting. However, these models pertain to this research due to recent advances and successful integration with Geographic Information Systems (GIS) [20,21].

To aid in the location-selection process, the authors discuss the relevant literature regarding GIS usage with utility systems, electrical distribution in developing countries, and the need for alternative lighting sources, particularly in Cambodia. After describing six datasets, the authors employ a consecutive series of spatial analytical procedures and heuristic methods to identify an appropriate distribution site. Following the results, the final section explores the implications of these results, several avenues for future research, and possible applications for rural, LED lighting systems in other developing countries.

## 2. Literature review

With the availability and acceptance of GIS tools and methods for spatial analyses, researchers can focus specifically on utility systems. The historic development of data models in GIS encourages the modeling of connected edges and junctions into networks [22,23], and these structures are ideal for the modeling of utility networks [24–28]. The industry leading GIS software producer identifies utilities as one of its most important market segments [29].

The published literature for developing countries addresses electrical utilities. To explore electrical distribution, a recent special issue of *Socio-Economic Planning Sciences* [30] provides detailed reviews of electrical provision models with particular focus on deregulation in developed [31,32] and developing [33,34] countries. To date, assessments of rural electrical access for developing countries and regions include India [6,35–39], sub-Saharan Africa [5,40–42], Zambia [43], Mali [44], Kenya [45], Guatemala [46], and Thailand [47], among others.

With regard to rural electric utility delivery, most of the literature on developing nations does not pertain to expensive grid extensions that are time consuming to install, but rather, explores alternative, distributed power generation that is low cost and environmentally friendly. The implementation of alternatives, such as solar powered electricity for generation and distribution over a broad, rural geographical area, is a relatively new idea. Distribution research indicates that later-developing countries appear to diffuse alternative technologies faster than developed countries, but foreign investments do not appear to accelerate this process

[48]. With local investment and micro-credit, alternative technologies may diffuse rapidly in developing countries. The potential viability of one of these alternatives, LED lighting, remains undocumented in the academic literature.

The authors recognize this gap in the literature, and this void motivates the methodology in this research. Data sources, other than published literature, can provide a mechanism to evaluate lighting need. An investigation of world-scale data demonstrates that several countries have an extreme need for nighttime lighting. By comparing nighttime satellite imagery and other data sources in the Rural-Urban Mapping Project [49], researchers can assess the urban populations of the world. These data show that 14 countries have five or fewer nighttime urban agglomerations and less than 25% of their population in urban extents [49]. Of the 14 countries, Cambodia has the second largest population. A considerable, rural population without nighttime lighting provides a strong incentive for considering alternative electrical systems within Cambodia.

Cambodia provides an ideal setting for using GIS to evaluate alternative electrical systems and to address the need for lighting. Cambodia, which borders the countries of Laos, Thailand, and Vietnam, has a population of 14 million citizens [50] in an area slightly smaller than Oklahoma. This developing country has a substantial population without access to electricity (~80% in 2004) [51], and a large percentage of the population will not have grid-quality electricity by 2030 [52]. Additionally, published research does not address locating a lighting distribution facility under the unusual constraints of landmines, which are prevalent in Cambodia – a recently war-worn country.

The government of Cambodia recognizes these needs and has set a goal of 70% rural electrification by 2030 [52]. Generally, the maximal covering location model mirrors the problem of providing electricity to a dispersed population. Due to budget constraints, electricity generation occurs at a limited number of locations. The distribution system then transmits electricity over lines that have known power losses. By balancing the extent of distribution lines against line losses and carefully selecting the locations of electricity generation, the government should be able to ensure that the maximal population has service. However, due to the enormous cost of expanding the infrastructure, the Cambodian government has ruled out the option of extending the distribution system beyond the capacity of the existing grid. Therefore, the government must explore alternative energy generation and distribution options for rural electrification.

The single work that investigates rural access to electricity in Cambodia focuses on biomass gasification and willingness to pay for electrical service. According to the research, biomass gasification, based on tree farming, is a viable option for 60% of the rural villages expected to be without electricity by 2010 [52]. Even under this ideal assumption, 40% of the villages require another off-grid option. Nassen et al. [53] note that rural, solar powered lighting, known as photovoltaics, are cost competitive to a point. However, as demand increases with household electrical appliances, grid extensions – with higher capacity – become the only viable option.

Individual families can arrange a micro-credit purchase of solar photovoltaic systems with rechargeable batteries to provide sufficient electricity for nighttime lighting and small appliances. LUTWs LED technology requires minimal charging to light residential homes. For lighting purposes, the 5-W system charges in 4.8 h of sunlight and operates for 9–28 h. The 10-W home version, which is also dimmable, operates on a battery for 15–45 h. This level of access to electricity, especially for lighting needs, can dramatically increase the ability of family members to pursue educational opportunities. In some instances, this access may be a temporary step until the government or another entity can develop grid extensions or electrification options.

In summary, this introductory review documents three points. First, access to electricity in rural areas of developing countries can have substantial social benefits. Second, the location of facilities for the distribution of resources in these areas shares elements with classical optimal location analyses, yet GIS techniques and tools are the preferred sources for the quantitative methods that can solve these problems. Third, Cambodia, with its extreme needs and personal safety issues, provides an ideal setting to develop a template for locating and distributing lighting systems. This article fills a gap in the literature and addresses these points by presenting a series of GIS-centered and network-based analyses that inform decision making for the location of an LED lighting facility in Cambodia.

### 3. Data

For this study, the authors evaluate primary and supporting datasets to determine the most appropriate distribution location. Primary datasets list electrical access areas, significant water features, known landmine locations, and local demographic data. To aid in distribution activities, supporting datasets include administrative boundary layers and accessible, paved roads. The following paragraphs discuss each of the datasets.

To determine areas with electrical access, private companies operating in utility management areas publish information relating to the distribution of electricity [54]. The exception is the state-owned electric utility, Electricite du Cambodge (EdC), which mainly serves the area surrounding Phnom Penh [52]. By combining information from these data sources, the first dataset comprises a list of the areas with electrical grid access.

The second primary dataset includes areas seasonally inundated by water and mainly relates to Cambodia's most distinctive geographical feature, the Tonle Sap (Great Lake). Since three quarters of the country lies at elevations of less than 100 m [55], many areas, including those surrounding the Tonle Sap, are prone to seasonal flooding. For example, the Tonle Sap, which measures nearly

2600 km<sup>2</sup> during the dry season, floods an area of approximately 13,000 km<sup>2</sup> during monsoons [56].

To determine hazardous areas, the third primary dataset correlates the location of landmines and unexploded ordnance with the surrounding communes [54]. This situation is ubiquitous in Cambodia and may be pertinent for other developing nations with a recent history of war. With GIS, the authors evaluate these datasets to exclude inappropriate locations and focus on areas without electrical access, seasonal flooding, or hazardous landmines.

Because the intention of distributing a lighting system is to assist residents with the greatest need, the fourth primary dataset identifies the population's geographic and socio-economic characteristics. Census data, as the source of population and poverty information, are available from 1998. This is the first enumeration in decades, and another census is currently in progress. To bridge this gap, and to identify additional attributes for locating the population in need, this project analyzes a 2006 study by the Danish International Development Assistance Program [54] and a 2004 survey completed by Cambodia's National Institute of Statistics [57].

Administratively, Cambodia has 24 provinces that often include the four large municipalities, Pailin, Keb, Krong Preah Sihanouk, and Phnom Penh (Fig. 1). The provinces subdivide into 177–183 districts, and districts subdivide into 1540–1621 communes, the smallest administrative unit. The country contains 13,406 villages. At all levels of geography, the number of areas varies according to the data source and appears to be largely inconsistent. These discrepancies are due to differences in the classification of areas as “communes” versus “districts” and splits or combinations of communes across datasets. When discrepancies occur between attributes and polygons, the researchers match the attribute data to the appropriate communal polygon [54,58]. The supporting spatial dataset in these analyses contains 24 provinces, 177 districts, and 1540 communes.

To determine measures of access, the authors utilize a network dataset [58] that contains 835 roads with eight major highways.

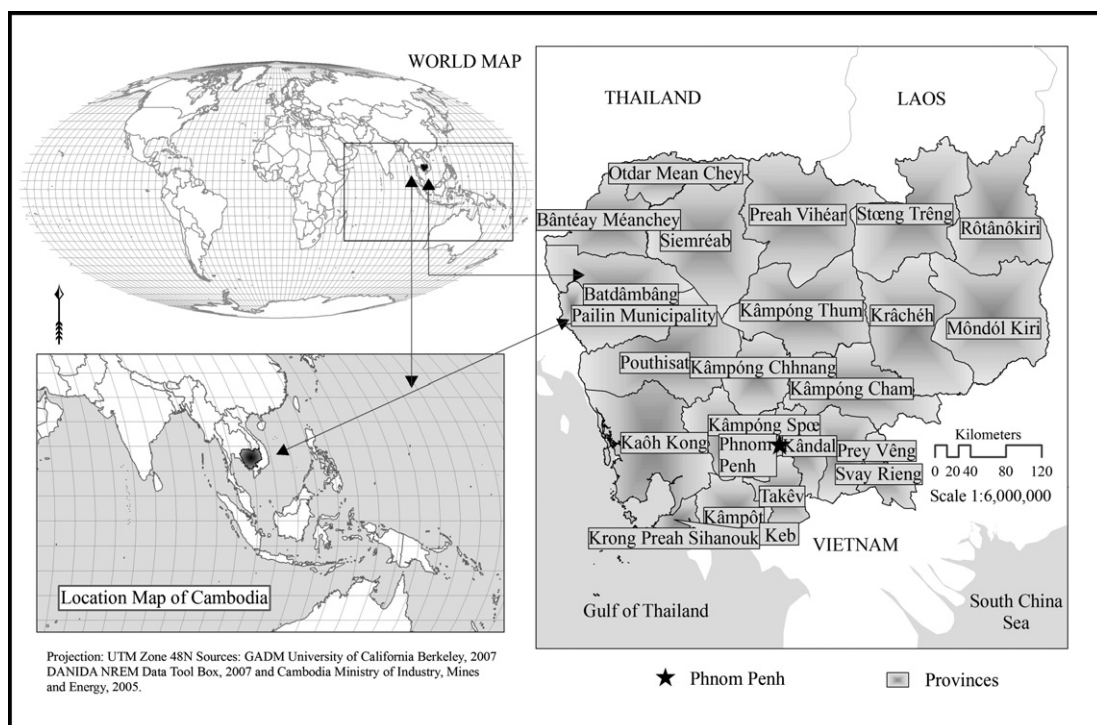


Fig. 1. Location Map of Cambodia.

Since the available dataset contains only a fraction of the roads listed in several non-spatial sources, the authors use remotely sensed imagery to verify the network. With a match between the spatial dataset and the imagery, there is confidence that the network dataset is as accurate a representation as is possible at this time.

**4. Methods**

The methodology in this research employs two primary steps, with several sub-processes within each step. First, the researchers use the datasets in a sequential selection process to eliminate areas that are inappropriate for a distribution location. Inappropriate communes include those with grid access, seasonal flooding, or hazardous ordnance within their borders. Second, the authors evaluate the demographic characteristics and the relative locations of the communes to site a facility that serves the greatest population in need. The following sections describe each step in detail.

*4.1. Removal of inappropriate sites*

To select an LED distribution site within Cambodia, the first step is to eliminate communes that either do not need lighting due to existing electrical service, or represent inappropriate locations due to terrain or security reasons. Therefore, the first eliminations include all areas with access to electricity. Twenty-four independent electrical systems provide power to the national and provincial capitals [59]. EdC supports a significant portion of the residents who live near the capital city of Phnom Penh and provides diesel or hydroelectric-powered electricity to six large towns. However, virtually no transmission links connect the load centers. Rural Electricity Enterprises supply limited service to additional areas throughout the country. Due to the extensive use of small generators in the rural areas and the high price of imported diesel fuel, residents pay some of the highest costs for electricity in the world [60].

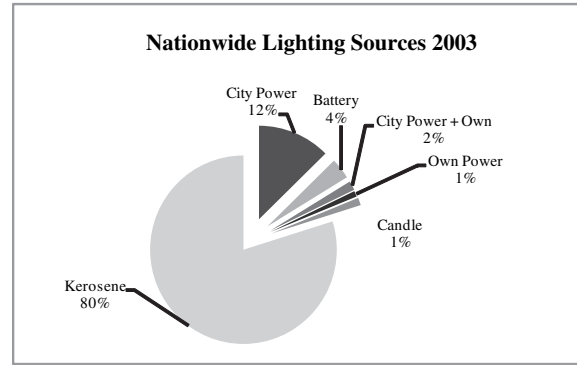


Fig. 3. Nationwide lighting sources [59].

Fig. 2 displays planned transmission lines, future proposed lines, and the maximum coverage for 22 kV electrical lines in 18 major cities. The 22 kV lines can extend for nearly 40 km from their source of electrical generation without significant losses. If the government were to provide electrical service to the extent of the technical potential, indicated by the areas covered with buffer circles, a substantial proportion of Cambodia’s population would have electrical service. However, the government has built only a small portion of the potential electrical lines. Without this extended and costly system, the residents have to meet their lighting needs through a variety of different sources (city power, private generators, kerosene, or battery), as portrayed by the fifteen regional pie charts in Fig. 2. With the exception of Phnom Penh, the country’s National Institute of Statistics finds that the main source of residential lighting is lamps fueled by kerosene (Fig. 3).

Cambodians use kerosene for lighting due to limited electrical generation and rotating service interruptions. Approximately 15% of the population has access to continuous electricity (Fig. 4) [60].

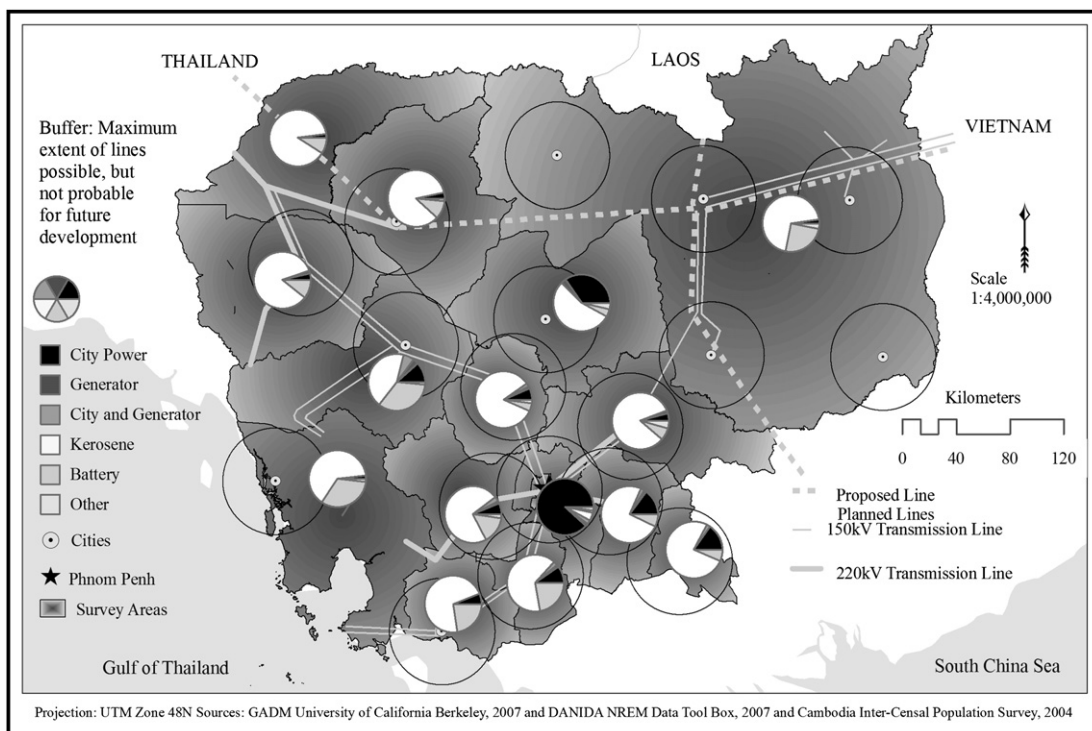


Fig. 2. Current Lighting Sources and Technical Extent.

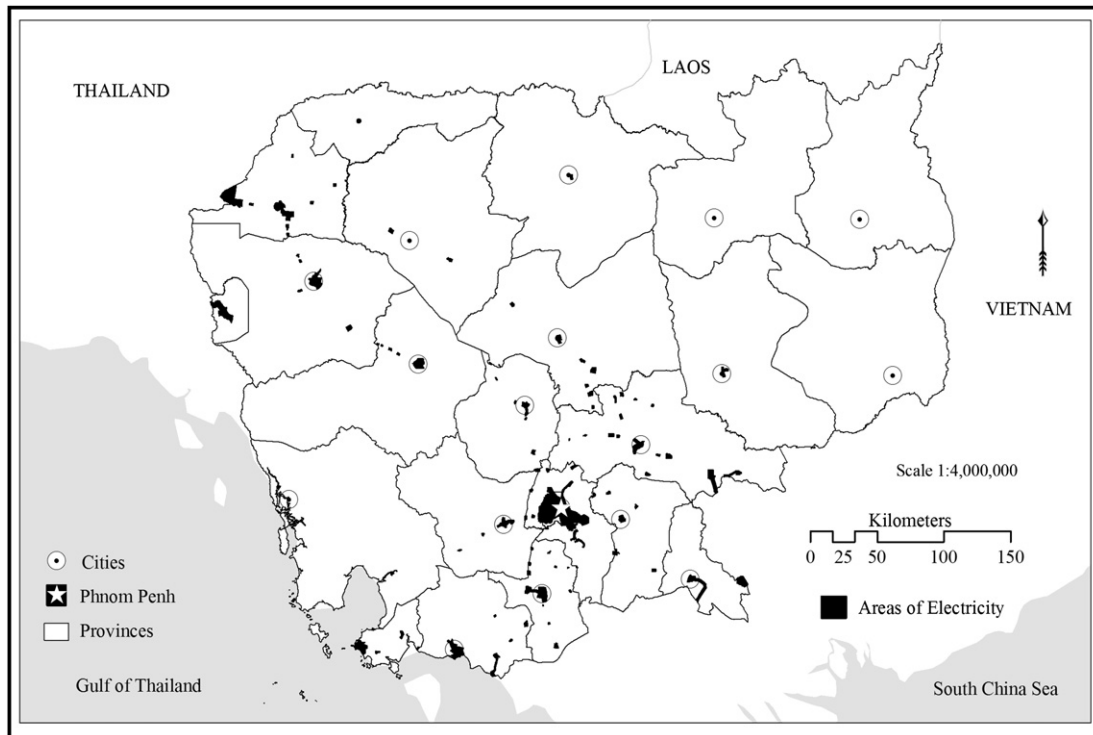


Fig. 4. Areas with Access to Electricity in Cambodia [61].

To eliminate these areas from consideration, the initial step in this process excludes communes with any electrical service, regardless of its reliability. With electricity providers at 110 locations [61], this step eliminates 394 of the 1540 communes.

The second exclusionary factor involves the potential for flooding. To avoid areas prone to seasonal flooding, the authors eliminate communes that intersect water areas—which are extensive in Cambodia. Based on the proximity to water, this

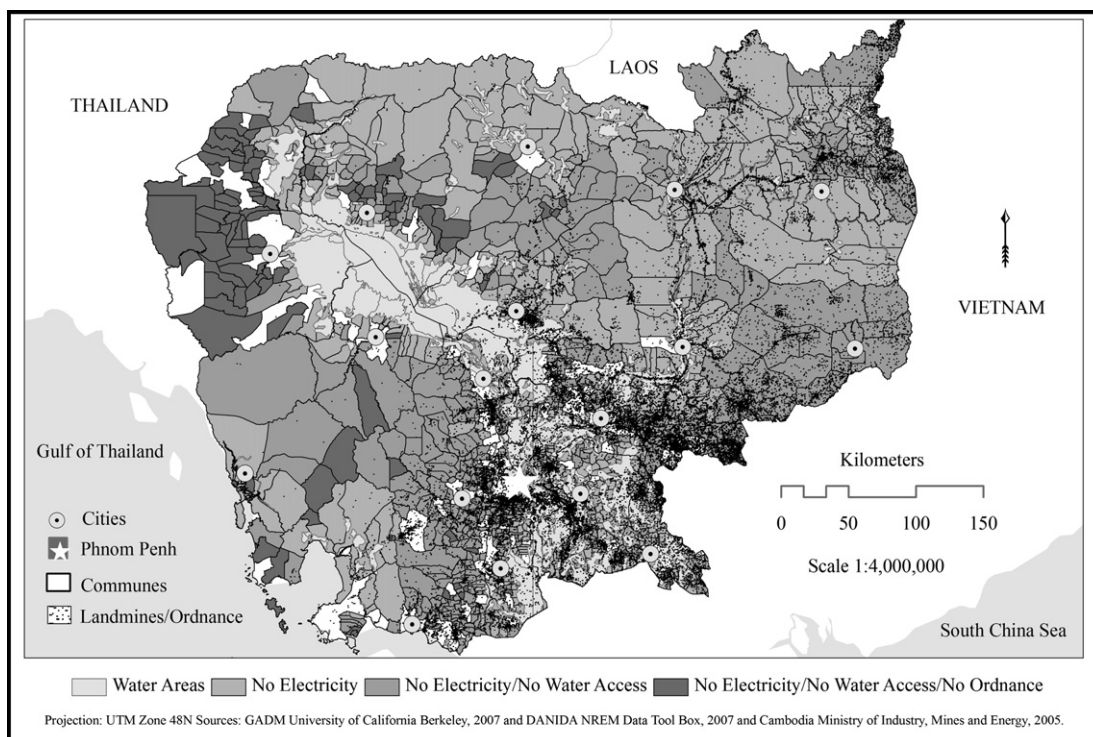


Fig. 5. Communes without Electricity, Water Access, or Ordnance.

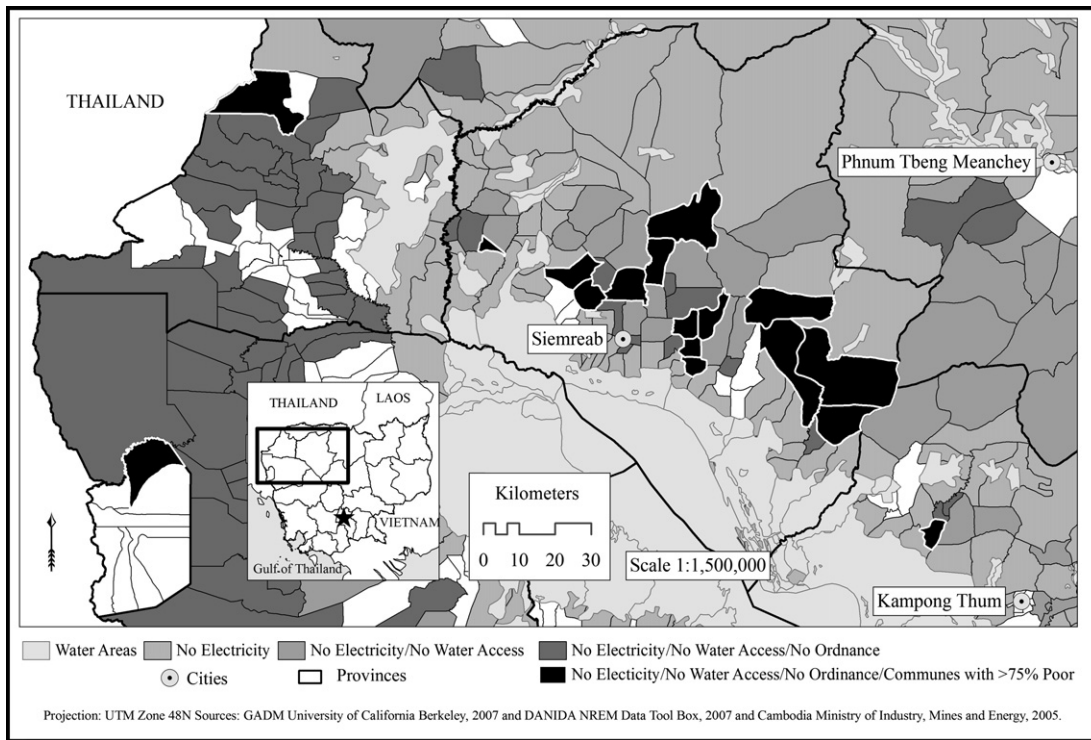


Fig. 6. Communes with Greater than 75% of the Population Categorized as Poor.

reduces the locations for consideration by an additional 675 communes.

The third crucial consideration in rural Cambodia is the location of landmines and other unexploded ordnance. According to the Landmine Monitor, officials reported 450 landmine-related casualties with 61 deaths in 2006 [62]. Since hazards exist within the country, Fig. 5 shows the areas to avoid due to landmines and unexploded ordnance. After reviewing the landmine information, this step in the analysis eliminates another 363 communes, leaving 108 communes as potential distribution center locations.

While the authors have taken care to make a reasonable interpretation of landmine and unexploded ordnance locations, the various spatial representations are not entirely consistent. Therefore, one cannot preclude the possibility of landmines in the areas selected for further consideration. Areas of the country are continually being tested and cleared of landmines and unexploded ordnance.

4.2. Selecting an appropriate location for the LED distribution center

The larger purpose of this research is to choose an appropriate site for one facility, not simply to eliminate inappropriate locations. The authors continue the site characterization studies in the preceding section with an evaluation of the population near the potential locations. As a correlate for lighting need and a measure of potential benefit to the population, the level of poverty is the next criterion for evaluation. For this analysis, the percentage of residents categorized as poor determines the value of this measure. Although the authors cannot ascertain the exact level of poverty in any given commune from the available data at this time, statistics indicate that 79 communes designate more than 75% of their population as poor. Fig. 6 highlights the communes with the poorest populations that also do not have access to grid electricity, border a water body, or contain known landmine locations. Of the

108 remaining communes, 2 do not have associated population values, and therefore, the level of poverty could not be determined. In order to focus on communes where statistics verify the need for lighting systems, this research does not include these unknown entities in further analyses. Of the remaining 106 communes, 17 have more than 75% of their population living in poverty. The majority of the nation's poorest residents live in the northwest sector of the country, particularly in the Siemreab province.

The Siemreab province, with its World Heritage Site, Angkor Wat, attracts hundreds of thousands of visitors to the region each year. Various organizations propose plans to supply electricity to this ancient urban area. In 2008, the Asian Development Bank

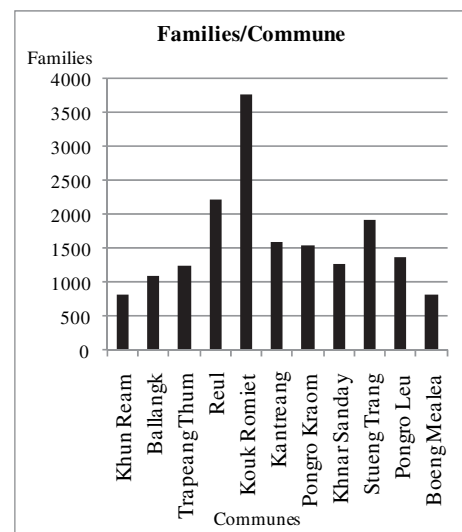


Fig. 7. Commune Families.

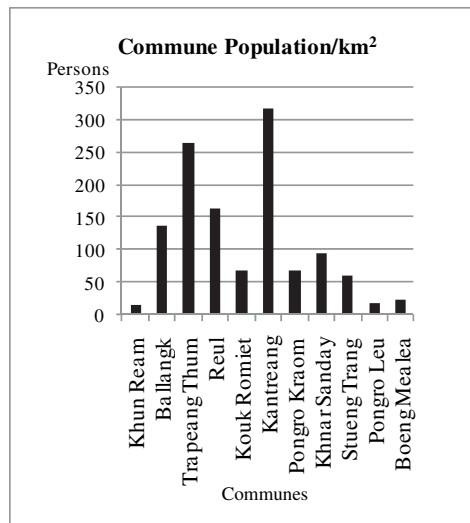


Fig. 8. Commune Population Density.

approved a \$7 million loan to build power lines from Thailand to the Siemreab tourist region surrounding Angkor Wat [63]. However, construction of the lines is still pending in Cambodia.

With delays in the construction of power lines, the network of roads becomes critical for the distribution of lighting units. According to a survey in 2004, Cambodia has more than 38,000 km of roads, but nearly 36,000 km remain unpaved [50]. The government now concentrates on paving the existing gravel and earth surfaces with asphalt, rather than building new roads. Since the authors plan to designate a single LED distribution site, the location must serve as great a population as possible within a reasonable distance. Access to major roads aids in this distribution process. A spatial intersection of the remaining 17 communes with a GIS data layer of the major roads eliminates an additional 6 communes from consideration.

Of the remaining 11 locations, the one that serves the greatest population is the most desirable. Ideally, since households use lighting, this is the preferred level of distribution. However, household information is not available at this time. As a proxy for households, the researchers rank each commune by population (number of families), as well as population density (Figs. 7 and 8 and Table 1). These are simple assumptions to reach the greatest population, but a decision based solely on these statistics could select a commune with a larger population that has a considerable spatial separation from the other communes with a substantial need for lighting. Fig. 7 shows the number of families by commune.

Table 1

Ranking of Communes by Families, Density, Number of Families within an 8 km Network, Number of Families in need within an 8 km Network and Distances Calculated with Origin-Destination Cost Matrices.

Communes	Families in Commune	Rank	Density Persons/km <sup>2</sup>	Rank	Families in Communes within 8 km Network	Rank	Families in High-need Communes within 8 km Network	Rank	OD Matrix Distances to All Other Communes (km)	Rank	Total Score	Overall Rank
Kantreang	1595	4	316	1	9044	2	3938	1	706	1	9	1
Trapeang Thum	1247	8	265	2	10563	1	2842	4	719	2	17	2
Reul	2214	2	163	3	6817	3	2214	6	890	5	19	3
Kouk Romiet	3768	1	66	7	5343	4	3768	2	1862	10	24	4
Pongro Kraom	1539	5	67	6	4586	5	2911	3	1043	8	27	5
Ballangk	1096	9	137	4	3984	7	2691	5	730	3	28	6
Khnar Sanday	1271	7	94	5	4177	6	2094	7	831	4	29	7
Stueng Trang	1917	3	59	8	1917	10	1917	9	2221	11	41	8
Khun Ream	823	11	14	11	3956	8	2094	8	914	6	44	9
Pongro Leu	1371	6	18	10	3312	9	1372	10	1124	9	44	9
Boeng Mealea	828	10	22	9	828	11	828	11	918	7	48	11

The commune with the largest number of families, Kouk Romiet, has a substantial separation from the other potential locations (Fig. 9). Thus, a distribution center in this commune serves its population, but it does not benefit the other communes with substantial need. Moreover, the population density of Kouk Romiet is one of the lowest among the remaining potential locations (Fig. 8). Therefore, its population may be difficult to serve given the relatively large size of the commune.

Due to the limitations of these simple population and density measures, the authors review a third option for distribution potential – service areas. Service areas allow one to measure the population that can easily travel a predetermined distance to purchase a product at a distribution site. Within the country, motorcycles and boats are means of transportation, but with limited car ownership or usage, bicycles are the most popular mode of transportation – particularly in poor and rural areas [54]. Therefore, the researchers use an appropriate bicycle travel distance to determine the facility service areas. A review of bicycle surveys [64–67] shows that the typical commuting distances range from 1.6 km to 8 km. Given the flat terrain of the Siemreab province, the location for the majority of communes under consideration, and the increase in bicycle purchases due to the cost of fuel for low-income residents in developing countries [67,68], the longer distance determines the service area boundaries. Fig. 9 illustrates the location of these 8 km service areas.

By using the service areas along the roads network, the researchers generate additional measures for ranking the communes. The first ranks the number of families living in all communes within the 8 km service distance, and the second ranks the number of families in the final 11 communes that are most in need of lighting. Fig. 10 displays the values of these measures.

In addition to total families, population densities, and service areas, a fourth measure of consideration is the travel distances between each location and the remaining communes. To evaluate this measure, the authors create origin-destination (OD) cost matrices for each commune. This last measure requires solving the one-median or Weber problem from classical location theory [69]. An application of the problem to this research describes the costs each commune incurs while acting as a distribution center to all other high-need communes. Fig. 11 graphically exhibits the values of this measure, and Table 1 enumerates the values. Lower total distances represent a more efficient location for distribution.

5. Results

This study scores the final 11 communes according to five measures: commune families, population density, network

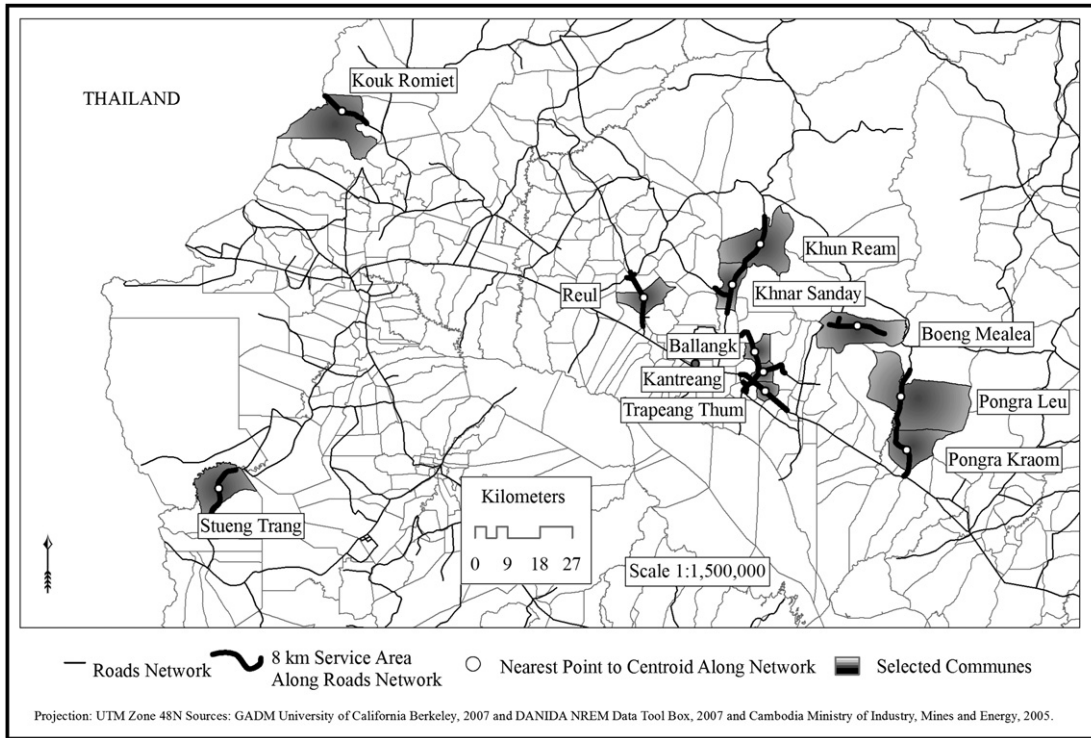


Fig. 9. Commune Service Areas along Roads Network.

families, high-need communes, and travel distances. The scores determine the ranking on a scale from one to eleven, and the sum of the rankings determines the overall results (Table 1). In addition to being easy to calculate, this type of ranking, known as a Borda ranking, provides two benefits. First, summing the ranks provides a holistic means to evaluate each commune. Second, if the highest-ranking location were unavailable, the service provider (LUTW) has a list of alternate locations.

Although Borda ranking is conceptually simple, it suffers from potential difficulties [70]. First, with the discovery of information that makes an alternative unacceptable or irrelevant, the order of the ranking could change in the absence of that alternative [71]. This is a concern when officials use Borda counts in voting systems,

particularly when they disqualify a candidate or a candidate chooses to withdraw from a race. In the case of ranking locations, the locations cannot withdraw, but if additional information were to make one or more of the sites undesirable in the future, the rankings could change. The researcher must repeat the ranking, rather than take the next alternative from the original listing. Second, tactical or strategic voting may influence the ranking outcome with Borda counts. Since the authors base the rankings in this study on objective, quantitative measures of fitness, rather than on subjective voting by judges, subjectivity is not an issue in

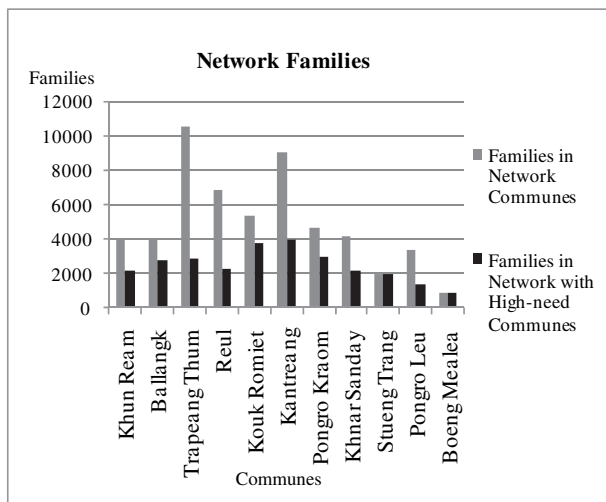


Fig. 10. Families within 8 km Network and Network Families in High-need Communes.

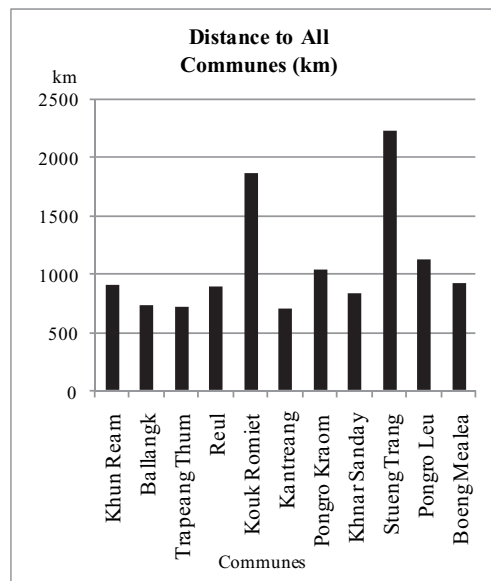


Fig. 11. Distance Totals for Origin-Destination Cost Matrices.



this case. By repeating a ranking with irrelevant alternatives and avoiding subjectivity that influences voting, researchers can circumvent these potential difficulties with Borda ranking.

In this study, the commune with the best overall ranking is Kantreang. Although Kantreang has the fourth highest population within its borders, it has the highest population density, the highest number of families within high-need communes, and the shortest travel distances to each of the other communes in need. It ranks second in the number of families within communes in the service area. In addition, a humanitarian organization recently completed a concrete water gate to replace an earthen levee that previously failed and left the residents in even greater need while dealing with a severe food shortage, transportation limitations, and economic difficulties [72]. Trapeang Thum, with the highest number of network families within the service area, ranks second. Reul ranks third.

## 6. Conclusions and future research

The objective of this research is to generate a method for using GIS and spatial analyses to determine a location for an LED distribution facility. Within the context of a Cambodian case study, this method employs a range of GIS techniques with several common data layers to eliminate as many inappropriate locations for distribution as possible. Further analyses use network measures of accessibility to determine an appropriate, centrally located site among suitable alternatives. Although the data are unique to Cambodia, anyone with access to industry-standard GIS software can utilize the ranking method as a decision tool for evaluating different factors in any developing country. Through expert input or a Delphi decision making process, weighting factors could enhance the ranking of alternatives. Moreover, the rankings do not specify a site that one *must* choose without the consideration of other factors. If additional information were to become available, lower-ranking sites may become more attractive and could be re-evaluated. The ranking represents a starting point to evaluate potential locations.

The greater goals of this research are to attract attention in the peer-reviewed literature to severely underdeveloped areas (Cambodia in particular), to inform the academic and research communities regarding the potential of LED lighting systems, and to suggest that planning tools can play an important role to improve the quality of life in other nations. The methods presented here are easy to duplicate at low cost. Any non-governmental organization can implement them.

Future research will seek to develop methods for solving the problem of locating multiple facilities rather than a single distribution center. Solving these p-median problems requires the integration of GIS technology and combinatorial optimization software [15]. Alternatives, such as covering objectives, may help determine priorities for LED distribution projects. Measures of potential distribution success can help determine where in the developing world to concentrate efforts, and what types of activities to encourage with LED lighting. Each activity and decision for community distribution is unique, and support projects already involve schools, theaters, hospitals, cultural centers, and emergency shelters. All of these are dependent on the availability of lighting. Most importantly, while the residents of developing countries wait for electrical generation, humanitarian organizations with technologically advanced, environmentally friendly, and energy efficient LED alternatives can address lighting needs now.

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