# Green Space Network in Nakhonratchasima City Municipality, Thailand

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**Abstract**

Urban green space still is one critical role for developing sustainability of cities that well-planed and well-designed green networks can create attractive settings for daily life, distinctive local identities for places and can help guide future settlement growth. Therefore, this study aims to plan green space network (GSN) or urban greenways' network in Nakhonratchasima City Municipality (NCM), Thailand. This GSN in NCM used GIS techniques such as the least-cost path analysis in ArcGIS, it was analyzed by the selected output of road nodes' and green space nodes' location. As results, the obtained GSN in NCM was found that Mittraphap Road (Highway no.2), cuts through the middle of NCM area as main potential green space location to connect other minor potential green space locations.

Consequently, this obtained GSN can help not only in local decision-making for planning and designing green city of NCM, but also in Thai city municipal areas to use its future approach or case study for their green areas.

**Keywords:** Green space network, Urban landscape planning, Geographical information system.

## 1. Introduction

According to 1 of 17 Sustainable Development Goals (SDGs) has set sustainable cities and communities (Goal no.11), focuses on implementing inclusive, resilient and sustainable urban development policies and practices that prioritize access to basic services, affordable housing, efficient transportation and green spaces for all [1]. This SDG goal has been set targets no. 11.7 is relevant to provide access to safe and inclusive green and public spaces, by 2030, provide universal access to safe, inclusive, and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities [2]. A part of this target stresses the "creating of green public spaces" which cannot be achieved without significantly transforming the way we build and manage our urban spaces [3]. Moreover, this target is proposed by two main indicators [4]: 1) ratio of land consumption rate to population growth rate, at comparable scale (to be developed) and 2) Area of public and green space as a proportion of total city space. Therefore, green space network is a strategic network connecting various habitats and species, urban and rural green spaces to each other and the communities around them that it offers a wide range of social, health economic and environmental benefits [5], for example, planning and design of urban green networks in Stockholm [6], metropolitan Melbourne's open space network [7], the Baltimore green network [8], the connectivity of urban public green space in an empirical study of Wuhan [9], the green network of Madrid community [10], construction of urban green space network in Kashgar city of China [11], and Significance of urban green space network Formysuru city, India [12].

From the reasons and importance mentioned above, this study aims to apply Geographical Information System (GIS) for analyzing green space network from finding the most possible and suitable spaces including ground checking. This study focused on area of Nakhonratchasima City

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Municipality (NCM) in Thailand because report of NCM land use between 2007-2019 [13], [14] were found that there was the least ratio of green areas about 0.16% and ratio of the most urban and built-up areas (about 83.64 - 87.67%). Although there was more NCM green spaces in year 2020 [15], was about 3.30 km2 or 8.74% of NCM area. However, there is still very small areas in NCM. This affect to ratio of using green areas (per person) in NCM because NCM population has increased every year [16]. Moreover, NCM has been facing challenges in terms of biodiversity loss, green space loss and conflicts between green and blue and grey spaces (access to green spaces, such as forests, parks, grasslands, and recreational areas, and blue spaces, such as rivers, oceans, seas, and lakes, improves health and wellbeing [17]). Therefore, this study requires framework of Green Space Network (GSN) in NCM to see how to connect green spaces in a fragmented city as a functional network. Consequently, this obtained results of NCM-GSN framework will help for planning green areas' increasing, restoring and accessing where will be able to provide ecosystem services as functional green infrastructure further.

## 2. Theoretical background and related academic papers

### 2.1 Definition and Importance of Green Space Network

This study focuses on green space in urban area and uses definition of De Hass [18]: urban land, partly or completely covered with grass, trees, shrubs, or other vegetation including parks, community gardens and cemeteries, but also rooftop gardens and vertical gardens, meadows and woods, blue-green zone (it is urban water such as ditches, canals, inland waterways and rivers and riverbanks). Moreover, urban green spaces provide many functions in urban context that benefits people's quality of life so there is a wide consensus about the importance and value of urban green spaces in cities towards planning and constructing sustainable or eco-cities of 21st century [19]. One critical strategy ever used for planning green city as Green Space Network (GSN) that would help to reduce green areas' landscape fragmentation and increase the shape complexity of green space patches and connectivity [20]. Generally, GSN is a strategic network connection between artificial and natural areas that is always implemented in green city development to increase, restore, and link green ways for accessibility of convenient all people [19]. Therefore, the study of urban GSN relates to the recreational and the cultural essence of an urban fabric which helps in maintaining and restoring the urban ecology [12]. A fair distribution of the urban green spaces all over the city caters accessibility for each and every inhabitant of the city [19]. Having sufficient public space allows cities and regions to function efficiently and equitably that provides the rights of way required for streets and infrastructure (and their connectivity) as well as the green space necessary for recreation and the provision of ecosystem services [4]. Furthermore, the diagram below illustrates the idea of maximising the benefits an individual space can deliver and the value that can be added by connecting them into a green network [21] as Figure 1.

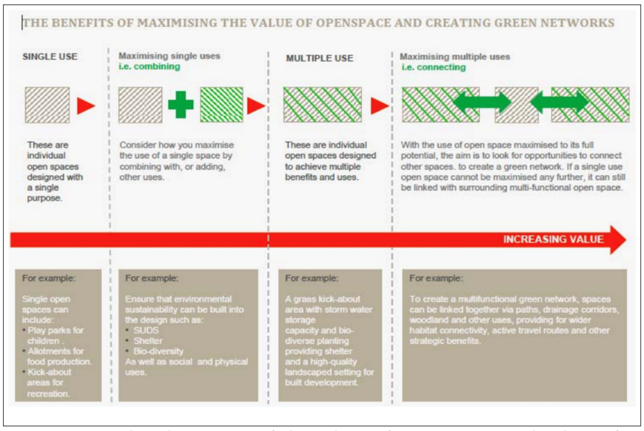


***Figure 1.*** *The diagram of the idea of maximising the benefits an individual space [21].*

### 2.2 Methods for Green Space Network

There are a variety of approaches and analysis of urban GSN from many related academic papers that are more specifically, the following are referred to be some examples:

- Xiu, Ignatieva and Bosch [6] used the concept of GSN that was expanded into a concrete analytical framework for studying green and blue linkages, as well as social and ecological connections and integrations. This study built a set of criteria to select node patches: 1) the land patches which can be potential habitats in biotope map for crested tit and common toad, and commonly used habitats in sociotype map for humans; 2) large areas of habitats suffer more acutely from landscape fragmentation, so we selected larger habitats as high priority of connection. The minimum area of patches was 1 ha; 3) the patches' central point should be located inside of area because irregular polygons of habitats may center outside the graphs.

- Yashaswini and Shankar [12] analyzed Urban GSN of Mysuru city in India was evaluated with a methodological framework to understand the scenario of GSN in densely built urban area. The urban green space per capita and accessibility of all the present green spaces are studies to know its functionality. As it is well known fact that the quality of life, human well-being are the important factors influenced by urban green and open spaces accessibility and also helps in improving the strategic lifestyle in the urban areas. Eventually, contributions from UGS to the urban areas are very broad and multidimensional like, social, cultural, recreational, economic, environmental and aesthetical.

- Mougiiakou and Photis [22] proposed methodological framework includes accessibility of residents to large green spaces, in relation to population density of blocks. It is important to identify the blocks that meet the fewer criteria, according to Accessible Natural Greenspace Standards (ANGSt), or those that are most populated and have less access to quality green, with an easy and quick way. At the same time, the output of initial evaluation can directly be used in the next step, as a criterion for the formation of the cost raster. In this way, blocks' degraded parts can be improved from the green corridors. The formation of a cost raster, which will include the whole number of the criteria (ecological, environmental, urban, and bioclimatic), will finally lead to the creation of connection paths; not only to the formation of green corridors but also green spaces (existing and new) and of the - necessary - stepping stones and to the interconnected smaller patches.

- Comber, Brunsdon and Green [23] used a network analysis in GIS to access for different religious and ethnic groups, was compared with benchmark standards that form part of the UK government guidance on greenspace provision. Whilst the specific results are locally important (Indian, Hindu and Sikh groups were found to have limited access to greenspace in the city), the study shows how a GIS-based network analysis in conjunction with statistical analysis of socio-economic data can be used to analyze the equity of access to community goods and services.

- Saura and Pascual-Hortal [24], He and his team [25] and Scotland's Nature Agency [26] studied a habitat connectivity index for measuring functional connectivity. The metric used to calculate it is the Equivalent Connected Area (Probability of Connectivity or PC). The index is a value that allows us to see change over time in each region. Its calculation has considered the habitat area, the size and number of patches of habitat, how the habitat patches are arranged in the area under consideration, and the effect the different elements of the landscape has on species movements between habitat patches. Habitat connectivity has been shown as a percentage of the total habitat area as this allows a rapid visual comparison of the degree of connectivity in relation to the amount of habitat present.

## 3. Methodology

### 3.1 Study area

Nakhonratchasima City Municipality (NCM) is selected as case study for this study (Figure 2) where covers 37.78 sq.km. The study area is in the administrative bound of Ni-Muang sub-district, Muang district, Nakhon Ratchasima province in Thailand. These areas establish in northern east region of Thailand and located in Southeast Asia of Equator from 14°56′-15°00′N to 102°01′-102°08′E.

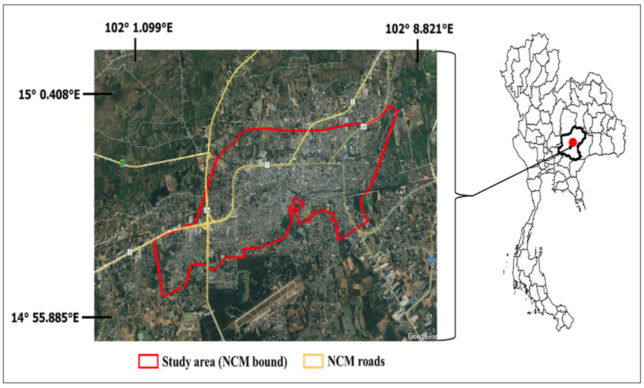


***Figure 2.*** *Nakhonratchasima City Municipality (NCM).*

3.2 Materials and Methods

This study collected available GIS data and sources for analyzing green space network in NCM as Table 1.

***Table 1.*** *Data collection and sources.*

| No. | GIS data collection | Sources |
|---|---|---|
| 1 | Land use data in year 2021 | Land Development Department (LDD) |
| 2 | Road data | NCM office |
| 3 | Green space data | |
| 4 | Others supplementary data e.g., building data | |

Remark: - All data collection were checked and updated by true ground checking and data of Google Earth program in year 2023.

Later, this study set the process for planning GSN based on connection of suitable spaces (road and green space locations). In this analysis, we used GIS techniques in ArcGIS as Figure 3 and more details as follows:

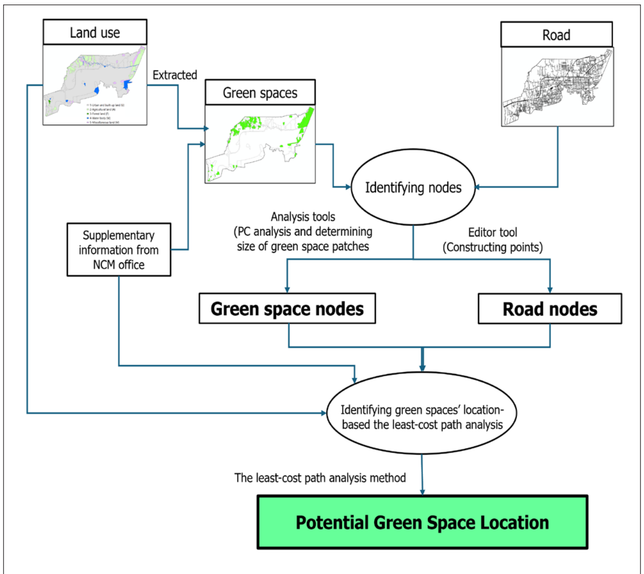


***Figure 3.*** *The process used to plan green space network in NCM.*

3.2.1 Creating Nodes for Roads and Green Spaces

1. Road nodes

Road nodes were created by using Editor menu (Constructor Points) to generate points along a road line in every 100 m. And then a destinating point were extracted to use in GSN analysis because this study focused on road accessibility and easement of traveling based on Mougiiakou and Photis [22] and perspective of ecosystem service in NCM context. This suitable road locations were used for finding the most possibility for GSN in NCM to integrate with green space location in the next topic.

2. Green space nodes

Green space nodes were created by using probability of connectivity (PC). Generally, PC is based on a probabilistic connections model, in which the dispersal probability $p_{ij}$ characterizes the feasibility of a step between patches $i$ and $j$, where a step is defined as a direct movement of a disperser between two habitat patches without passing by any other intermediate habitat patches. This is PC equation as below:

$$PC = \frac{\sum_{i=1}^{n}\sum_{i=1}^{n} a_i . a_j . p_{ij}^{*}}{A_L^2} \quad (1)$$

Where n is the total number of habitat nodes in the landscape, $a_i$ and $a_j$ are the attributes of nodes $i$ and $j$, $A_L$ is the maximum landscape attribute, and $p^*_{ij}$ is the maximum product probability of all paths between patches i and j. PC ranges from 0 to 1 and increase with improved connectivity.

The coefficient of variation (CV) is used to determine the threshold where the difference in the most stable importance index levels is most pronounce and to determine the final study threshold. Its formula is [27]:

$$CV = \frac{S}{dx} \quad (2)$$

Where S is the standard deviation of the importance value of the patch connectivity index, and $\overline{dx}$ is the mean of the importance value of the connectivity index. A more considerable CV value indicates a better dispersion of the importance value of the green space patches under this threshold and a more noticeable difference in rank, making it easier to select green space patch nodes.

3.2.2 Identifying Potential Green Space Location

In this paper, the least-cost path analysis method was used by calculating the cumulative cost from source to destination nodes of green spaces and roads based on the connectivity or patch area throughout the landscape. This analysis can be used to identify habitat connections that will preserve or improve connectivity [28] - [30] and then are determined by the minimum cost path between ecological nodes in a network of green spaces and identify potential green spaces [31].

Moreover, this study modified an important level of land use type from Li et al. [11] for supporting identification of potential green space location as shown in Table 2. This table presents the range of the important values of land use type that this study gave the highest weight on road factors because we focus on convenient access to travel by using vehicles and walking. Greenland, construction and others were set as the ordered important level of green space network in NCM, respectively.

***Table 2.*** *Land use type classification and important weights for green space network in NCM.*

| Factors | Description | Range of Impedance Values |
|---|---|---|
| Road | Available NCM-road | 4 |
| Greenland | Forest, agriculture, gardens, lawn, and others green spaces (little vegetation is present, though some areas have some planted vegetation (primarily shrubs and grasses) | 3 |
| Urban and built-up land | Residences, public facilities, municipal utilities, warehouses, industries. | 2 |
| Other | Lands are used for water, agriculture, abandon etc. | 1 |

Remark: Modified from Li et al. [11]

## 4. Results and Discussions

### 4.1 Distribution of The Existing Green Spaces

The random sampling-based true ground checking on 19-25 October 2013 for NCM land use as Figure 4A. The result of kappa coefficient showed 89.90%. And then this NCM land use was particularly extracted as GIS layer of green spaces including forest, agriculture and gardens as Figure 4B). The existing NCM land use included forest land (0.06 km2 or 0.16%), agriculture land (3.24 km2 or 8.58%), urban and built-up land (33.12 sq.km. or 87.67%), water body (1.04 sq.km. or 2.75%) and miscellaneous land (0.32 sq.km. or 0.85%). This NCM land use output showed that NCM green spaces (e.g., forest and agriculture in NCM) is still very small size about 3.30 km$^2$ (3,300,000 m$^2$) or 8.74% of NCM area. When it was compared to the minimum standard set by World Health Organization (WHO) of 9 m$^2$ green open space per city dweller [32], NCM green space (28.46 m$^2$ per city dweller) is still under such minimum WHO standard. However, we shouldn't neglect green spaces that they should preserve and find ways to increase green space.

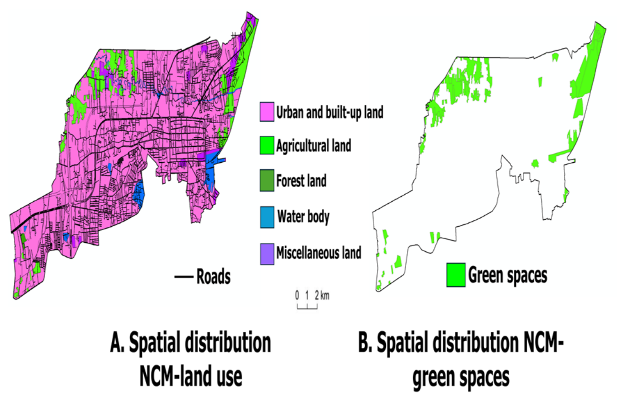


***Figure 4.*** *Spatial distribution NCM-land use and green spaces.*

### 4.2 Selection of Road Locations

In NCM area, there are 31 roads, include 3 highways and 28 urban roads. This study created new points along NCM roads using GIS techniques. There was the generated total 4, 835 points that were divided into 3,902 starting points and 933 destinating points along NCM roads (Figure 5A). However, this study found that there are 132 of 933 destinating points (14.15%) where were selected for analyzing potential GSN in NCM (as Figure 5B). These 132-selected destinating point based on criteria: road accessibility, easement of traveling and ecosystem services. Similarly, research of Marshall et al. [33] considered criteria in such factors to really benefit for city people. Moreover, we integrated perspective of ecosystem service in NCM context to select road nodes that related research of

Stanford et al. [34] gave importance to key social ecological characteristics.

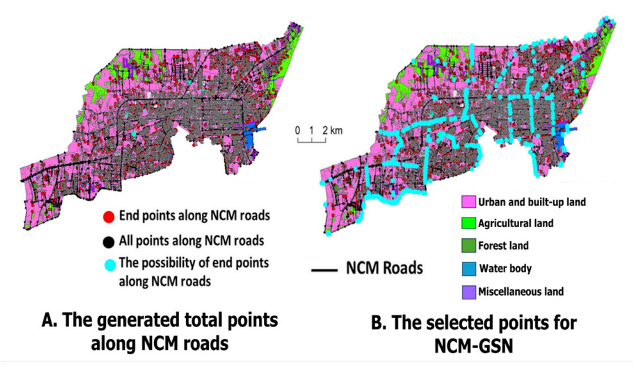


*Figure 5.* End points and total points along NCM roads.

### 4.3 Selection of Green Space Locations

Based on Figure 4B, there were 40 green space patches with an area range from minimum (700 $m^2$ or 0.01 $km^2$) to maximum (770,000 $m^2$ or 0.77 $km^2$). Therefore, the number of components (or connected region) was 40 when the threshold value was 0.01 $km^2$ and was 1 when threshold value was 0.77 $km^2$. Therefore, the threshold for connectivity was set at 0.01-0.77 $km^2$, with 0.01 gaps. And then Spearman' rank correlation coefficient was used for analyzing changes of the connectivity threshold. In this analysis, the probability of connectivity was determined the most stable when the threshold changes. After identifying probability of connectivity as a criterion for selecting nodes in a greenfield patch. We calculated its coefficient of variation as shown in Figure 6, when the threshold value is 0.01 km., the coefficient of variation (CV) of the significant value of probability of connection was the greatest (2.75), and the rank difference between patches in the research region was the greatest and most appropriate for selecting green space patch nodes as Figure 6. Consequently, there were 19 of 40 green patch nodes (47.50%) where were selected for analyzing potential GSN in NCM (as Figure 7). This obtained output is related to output of Li et al. [11] and Yashaswini and Shankar [12], have CV of the significant value of probability of connection in the same direction although distance thresholds are different each other.

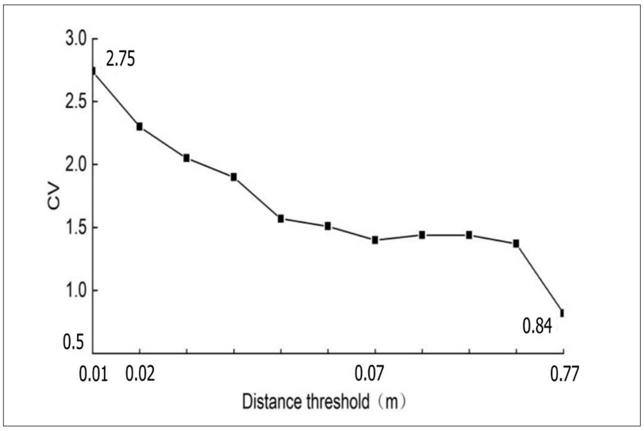


*Figure 6.* Coefficient of variation under different distance thresholds.

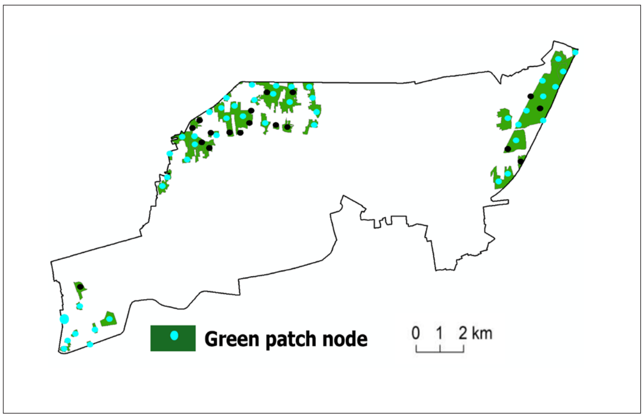


*Figure 7.* Spatial distribution of the selected green patch nodes in NCM.

### 4.4 Potential Green Space Network (GSN)

The potential GSN was selected by analyzing the output of road (Figure 5B) and green space locations (Figure. 7) to create GSN in NCM-based the least-cost path analysis. These GSN outputs were found that Mittraphap Road (Highway no.2), cuts through the middle of NCM area as main potential green space location to connect other minor potential green space locations as Figure. 8. This obtained GSN in NCM is likely common network typology of least cost user (see more details from Hellmund [35]). Based on the result of GSN in NCM above, it relates to the output of Li et al. [11], Yashaswini and Shankar [12] and Marshall et al. [33], most obtained GSN is always mainly proposed from middle point to spread around in city areas. Moreover, it is likely GSN output of Kong et al. [29] in project of scenarios for urban green space networks based on the gravity model and graph theory.


***Figure 8.*** *GSN construction in NCM.*

## 5. Conclusions

This existing NCM land use output showed that NCM green spaces (e.g., forest and agriculture in NCM) are still very small size about 3.30 km$^2$ (3,300,000 m$^2$) or 8.74% of NCM area. When it was compared to the minimum standard set by World Health Organization (WHO) of 9 m$^2$ green open space per city dweller.

For potential GSN-based the least-cost path analysis, it was analyzed by the selected output of road nodes' and green space nodes' location. The output of the obtained GSN in NCM-based was found that Mittraphap Road (Highway no.2), cuts through the middle of NCM area as main potential green space location to connect other minor potential green space locations.

Consequently, this obtained GSN can help not only in local decision-making for planning and designing green city of NCM, but also in Thai city municipal areas to use its future approach or case study for their green areas.

## 6. Acknowledgement

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