Green infrastructure conceptual framework for Kuala Lumpur

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Abstract. Kuala Lumpur (KL) undergoes significant development since Malaysia independence. Thus, the green spaces in KL are under increasing pressure of decreasing, which lead to fragmentation. Nevertheless, there is a question on how to do Green Infrastructure (GI) planning in KL spatially to solve this problem? The study outlines the conceptual framework of GI planning and establishment in KL. Firstly, a range of literature related to GI, landscape ecology principle, Morphology Spatial Pattern Analysis (MSPA) and landscape connectivity was studied. Subsequently, a conceptual framework was proposed to solve the green space fragmentation. The findings can be a starting point to conduct a GI plan in KL. The study ended by highlighting the main concept of GI in the spatial planning of KL, Malaysia.

Keywords: Green space, green network, fragmentation, connectivity, landscape ecology.

1. Introduction

Most developing-world cities continue to grow in population that causes a decrease in urban green spaces at the expense of built-up areas [1]. Furthermore, GI also lacks in Asian cities and urban development policies despite its multifunctionality [2]. Habitat fragmentation is defined as continuous habitats broken up, resulting in habitat degradation, isolation, and edge effects [3]. The phases of the geometric characteristics fragmentation process are perforation, incision, dissection, dissipation, shrinkage, and attrition [4]. Consequently, fragmentation results in a range of isolated habitats, ecosystems, or land-use types surrounded by a matrix of more heavily developed areas and lines, which alters the segment's ecological interrelationships [5].

Although there is a provision of green space by utilising the size of the development area approach in Malaysia, there are still fragmentation problems lying in urban green spaces around Klang Valley. Chan and Vu [6] posits that green space fragmentation in the Klang Valley is far more severe and should not be disregarded as green spaces have doubled in the last two decades. Nevertheless, a more significant proportion of urban green patches do not indicate a higher percentage of urban green spaces but indicating a higher percentage of scattered green patches [6]. In Kuala Lumpur, Rasli et al. [7] observed that spatial trends are affected by the growing urbanisation and related master planning strategies.

Furthermore, the concept of connectivity, especially in urban research, is underrepresented [8]. Liu et al. [9] also claim that conservation strategy involves securing crucial locations to improve overall connectivity, restoring connectivity barriers, and implementing different measures in the local context are still under research. In the Malaysian context, the establishment of the corridors is least acknowledged by the policies, as the Malaysia National Physical Plan only focuses on creating a central forest spine to restore the relation of scattered forest areas in Peninsular Malaysia. Hence, Malaysia development policymakers need to create green urban corridors [10].
The literature survey has revealed that the modelling of GI using Geographic Information System (GIS) is useful. However, there is not much GI planning research conducted in Malaysia. Thus, this study proposes a GI spatial provision conceptual framework to solve green space fragmentation and then simulate a connectivity model to create a GI plan using GIS based on landscape ecological principles.

2. Theory and tools
The study and modelling of the roles of space on ecological processes that influence ecological patterns, such as species distributions, is known as spatial ecology [11]. Landscape ecology analyses how spatial variability affects ecological processes and species distribution across various scales [12,13]. Ian McHarg argues that ecology should be the primary basis for urban planning [14]. GI focused on spatial conservation [15], and landscape ecology principle identifies hubs and corridors to form a GI [16].

Landscape ecology principle is the study of interactions among landscape elements. It deals with mosaics' spatial configuration on various ecological phenomena [17]. Thus, the landscape ecology principle is a theoretical basis for analysing complex and diverse landscapes [2]. GI consists of core/patches and link/corridors/network and matrix based on landscape ecology principles [14,16]. Figure 1 explains how the landscape ecology principle contributes to the establishment of GI graphically.

![Figure 1. Patch, corridor matrix explanation in graphic [18].](image-url)

The spatial pattern of patches, corridors, and matrix form a landscape that is a critical factor for functional flows and movements in the landscape [4]. This network system supports a crucial ecological process contributing to a sustainable landscape [19,20]. This is approved by Uy and Nakagoshi [21] study that connected green spaces ecological values are better than individual green spaces. Heymans et al. [22] said that securing biodiversity and the distribution of ecosystem functions and services can be achieved by having heterogeneous spatial elements of the landscape. Foreman and Godron [17] suggested patches, corridors and the matrix as the three primary component forms of every landscape. Landscape fragmentation decreased the patch area and increased the patch number [23]. Thus, there is a need to find out the patches and link the small patches in a concentrated way [24].

The basis of GI spatial provision is landscape ecology principles. However, this study also applies Morphology Spatial Pattern Analysis (MSPA in GUIDOS software), Graph theory (Conefor software) and least cost path with the assistance of transition management to guide the study. Both of this plugin is compatible with ArcGIS as a platform to prepare information and visualise the result. In Breuste et al. [25] and Chang et al. [26] study, MSPA was employed with landscape ecological planning principles applying GIS to come out with a structural GI plan. MSPA can automatically detect available patches and corridors [27]. MSPA derived from mathematical morphology and was subsequently applied to
image analysis and landscape ecology [9]. MSPA can evaluate structural landscape connectivity in assessments of GI [28] by using current intensity to identify GI elements and main areas that have a significant effect on the landscape [22,28]. Based on geometric concepts, MSPA can be applied at any size and to any image, and the foreground area of a binary image can be divided into seven crucial landscape types, namely core, bridge, islet, perforation, edge, loop, and branch from the perspective of the pattern process linkage [29]. MSPA uses the analogy of the MSPA pattern class: core representing network nodes and bridge representing network connections to provide an automated, accurate, and repeatable approach for setting up the network definition [30]. Given these benefits, applying MSPA to GI analysis will reveal new insights into essential network layout components [29]. In terms of connectivity, besides maintaining the current large-area core areas, it is efficient to fix the damaged patches in the bridging area, set stepping stones, and restore some minor links between the patches [22].

Functional connectivity is evaluated using Conefor sensinode, which is built on Graph Theory. Graphs allow us to identify patches that are critical for habitat connectivity and thus to protect long term population persistence across the landscape [31]. In this case, functional connectivity depends on the principle of habitat availability (reachability) at the landscape scale, using metrics such as the integral index of connectivity (IIC) and the probability of connectivity (PC) [32]. It also explains the probability of species movement in nodes with secondary ecological nodes in the high and low energy of landscape connectivity [33]. Conefor sensinode measures functional connectivity by requiring data on both the structural (the spatial organisation of habitat patches) and functional (the dispersion abilities of the species under study) components of connection. Conefor sensinode also requires two input text files (the node file and the connection file) and some additional user-specific settings, all shown in a simple interface on the software's main screen [34].

These measurements give a rather thorough picture of possible connectedness, although they only need a small amount of data. To define corridors, the study employs least-cost paths between core areas. The cost path tool was used in ArcGIS to build the least cost (most suitable) corridors connecting all parks/core patches. A suitability map creates a cost surface layer for the least-cost path assessment [35].

3. Conceptual framework

Figure 2 shows the proposed conceptual framework for GI. Thus, this study aimed to propose a spatial provision framework of GI to solve green space fragmentation and then simulate a connectivity model using GIS based on landscape ecological principles.

![Conceptual framework for KL GI spatial provision.](image)

Mell [36] posits that the actual definitions of GI are significantly different based on the study's objective and the practice of the researchers who published it. Furthermore, Mell et al. [37] claimed that the definition is affected by researchers or organisations and locality interpretation. Bartesaghi Koc et
al. [38] supported that geographical context played a crucial role in classifying GI and relies on the site-related conditions, research objectives, and country. Thus, identification of the individual element and linkage in a local context is crucial. Hence, there is a need to clarify what is GI before starting any project on it.

As demonstrated in Figure 2, there is a need to identify the hub or parcel of GI to increase the multifunctional level. Thus, by applying Ahern²ⁿ planning framework, the hub or parcel and network are identified. Afterwards, structural and functional connectivity are linked to create a GI plan that has higher multifunctionality. To guide the study to be more objective, transition management is employed with a planning framework as a goal. According to Loorbach and Rotmans [39], the general concepts of transition management sphere analysis are: strategic, tactical, operational and reflexive.

For this reason, the multifunctionality of GI could contribute to the sustainability of the site. The multifunctionality of GI reached a maximum when the individual elements such as parks, forests or green spaces (individuals) are linked (networks) and form a complete single GI, as shown in the red arrow in Figure 2. Furthermore, Davies et al. [40] pointed out the purpose of a GI plan is to ensure that the infrastructure's integrity and connectivity are improved. Different GI elements and their connections to form a network allow organisms to travel and matter to spread.

4. Conclusion and future prospect

In summary, landscape ecology principles provide the basis for identifying GI elements. Structural (MSPA) functional (graph theory) and least cost path contributed to connectivity that contributes to a higher level of multifunctionality. Finally, transition management provides a guide for study to be more objective. This framework allowed a chance of reconstructing GI subsequently lead to a better prospect of the urban environment.

5. References

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