Elevating Urban Ecology: Assessing the Connectivity of Skyrise Greenery in Singapore

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SKYRISE GREENERY, ECOLOGICAL CONNECTIVITY, NETWORK ANALYSIS, BIODIVERSITY CONSERVATION, URBAN ECOSYSTEMS, SUSTAINABLE URBAN DEVELOPMENT

BACKGROUND

In its ambition to evolve into a "City in Nature", Singapore is committed to adding 200 hectares of skyrise greenery into its urban landscape by 2030. Beyond their recreational functions, these elevated green spaces emerge as potential ecological hubs, enriching urban ecosystems through habitat provision and biodiversity enhancement. While most urban network studies consider the ground level greenery for its ecological connectivity and biodiversity value, the substantial skyrise greenery component is currently not accounted for as an integral component of the green network in the urban planning and design process.

This study presents a systematic methodology for assessing the ecological connectivity of vertically integrated urban green spaces at a neighbourhood scale, using the Wilmar and Solaris building within the city's one-north district as a prime example. The Solaris building is bound by roads on all four sides, while Wilmar building has one of its edges seamlessly integrated with a park at the ground. The study addresses two key research questions:

1) Does the proximity of ground-level greenery significantly improve the ecological connectivity of sky-rise greenery?
2) How can Network Theory be used to quantify and compare the ecological connectivity of sky-rise greenery?

Figure 1: View of Wilmar Building with its adjacent park

Figure 2: View of Solaris building with its adjacent roads

METHODS

MAPPING THE ECOLOGICAL NODES AND EDGES

DEFINING THE NODES
- every planted patch within the study areas is considered as a node, a potential habitat capable of supporting biodiversity
- each node is analysed for its quality of habitat provisioning using the following attributes : native/non native species, bird attracting, butterfly / caterpillar attracting, bat attracting, flowering/ non-flowering

DEFINING THE EDGES
- the closest distance between the edges of any two nodes is considered
- in the case of nodes being separated at different levels, the inclined distances are considered as the closest points between the edges

FULLY WEIGHTED NETWORK (FWN) ANALYSIS

NODE AND EDGE WEIGHTS
- in the connectivity analysis, each planted patch will perform differently based on its own plant composition and elements, thus the nodes are weighted based on the relative presence of habitat attracting plants
- edge weights are considered based on two key criteria, terrestrial species connectivity and aerial species connectivity.
- indicative species are squirrels, chameleons for terrestrial and birds, butterflies, bees for aerial
- the betweenness, closeness and degree centrality measures are derived with weighted nodes network analysis, the results consider not just the connectivity between the nodes but also how the nature of each node impacts the overall connectivity

PERFORMANCE EVALUATION

COMPARITIVE ANALYSIS
- we compare the results of the connectivity measures and derive the key differentiators if any due to the proximity of a park vs no park
- the analysis also looks at the connectivity for the terrestrial and aerial species to identify if there are any critical features influencing the habitat connectivity in the skyrise greenery using three radii of 25m, 50m and 100m
- overlay the different connectivity layers to identify the overlaps, which nodes are significant connectors for each network, and what attributes play a critical role in their performance

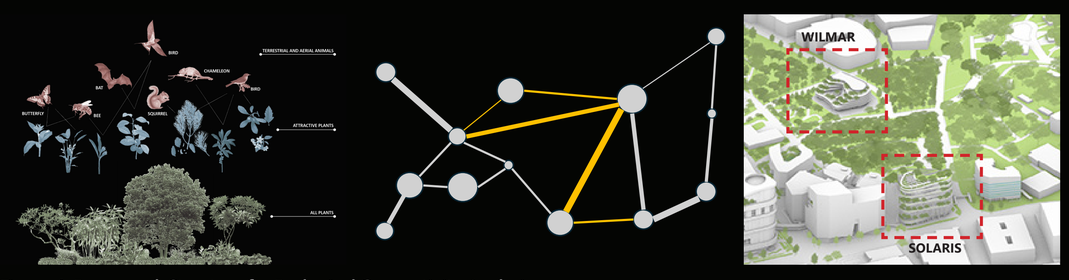

Figure 4: Framework Structure for Ecological Connectivity Analysis

ANALYSIS FRAMEWORK

Nodes Scores (Measurable parameters to establish the habitat provisioning quality)

Presence/Absence of
- planting structure
- native species
- bird attracting species
- butterfly / bee attracting species
- bat attracting species

Edges Properties (Determine how spaces connect and interact)
Closest distance between any two nodes (metric)

Centrality measures indicate the significance of the node

- Degree centrality:
Degree centrality indicates the number of connections of a node. The hypothesis is that for territorial species with limited range of movement, nodes with higher degree centrality may play a significant role in their territorial definitions.

- Closeness centrality:
Closeness centrality is reciprocal of the sum of the length of the shortest paths between the node and all other nodes in the graph. It indicates connectivity between nodes and defines clustering in a network. The measure is hypothesised to indicate the set of spaces that have the potential to become extended habitats for species.

- Betweenness centrality:
Betweenness centrality measures the extent to which a node lies on shortest paths between other nodes. It measures the criticalness of a node in the network. We hypothesise that nodes with high betweenness will have high biodiversity and habitat provisioning quality.

Comparison Table: Wilmar and Solaris Connectivity Measures

Conn_measure	Wilmar			Solaris		
25m radius	Mean	Max	Min	Mean	Max	Min
Degree centrality	14.56	34.00	3.00	7.23	14.00	3.00
Closeness centrality	0.32	19.49	0.08	0.11	0.58	-0.09
Betweenness centrality	22.79	1390.00	0.00	3.91	101.63	-1.32
50m radius						
Degree centrality	39.77	57.00	9.00	16.69	23	10
Closeness centrality	0.47	0.80	-0.11	0.16	0.73	-0.13
Betweenness centrality	7.05	27.92	-1.16	0.83	4.01	-1.35
100m radius						
Degree centrality	57.70	60.00	37.00	25.00	25	25
Closeness centrality	0.61	0.97	-0.15	0.21	1	-0.15
Betweenness centrality	0.75	1.64	-0.25	0.00	0	0

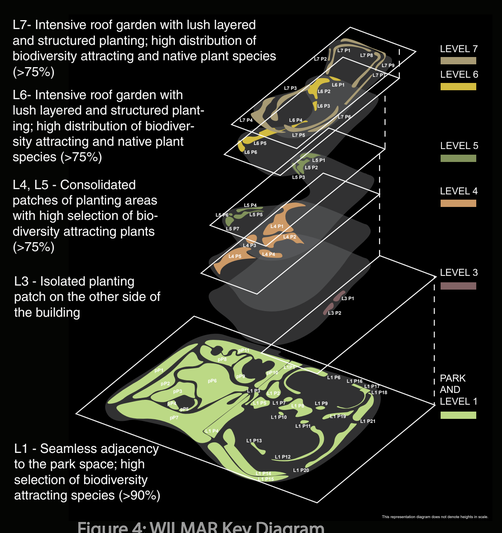

Figure 4: WILMAR Key Diagram

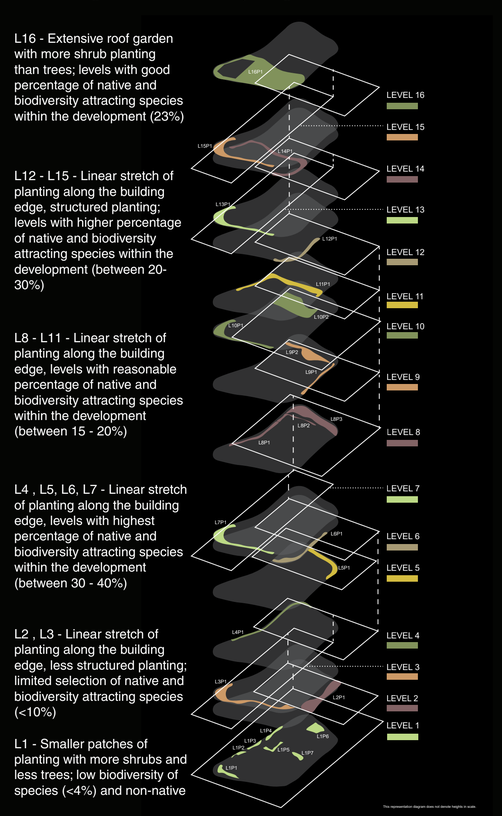

Figure 5: SOLARIS Key Diagram

PRELIMINARY RESULTS

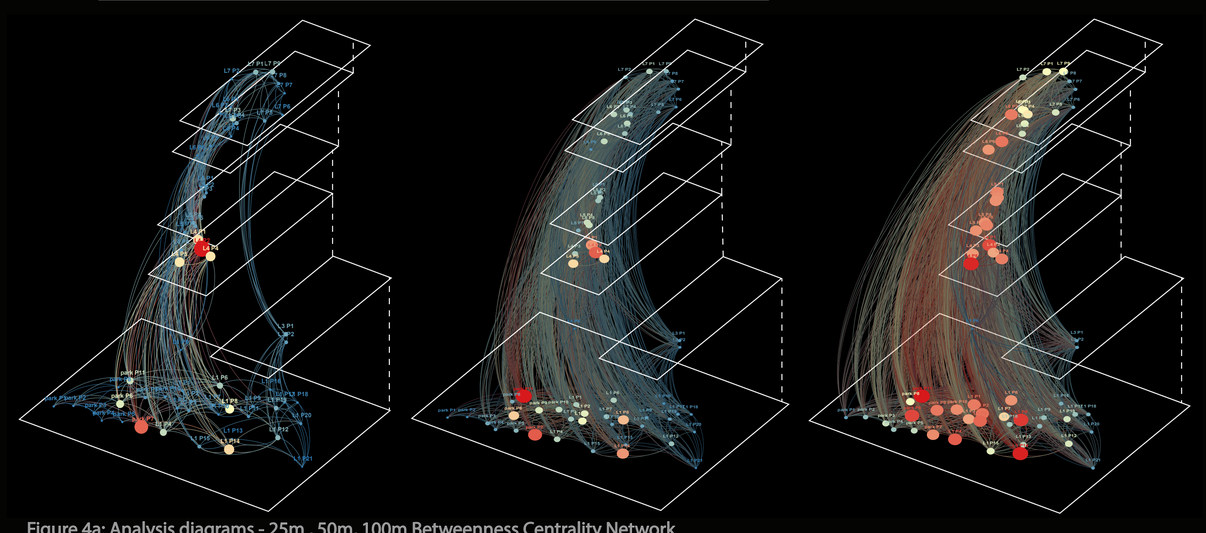

Figure 4a: Analysis diagrams - 25m , 50m, 100m Betweenness Centrality Network

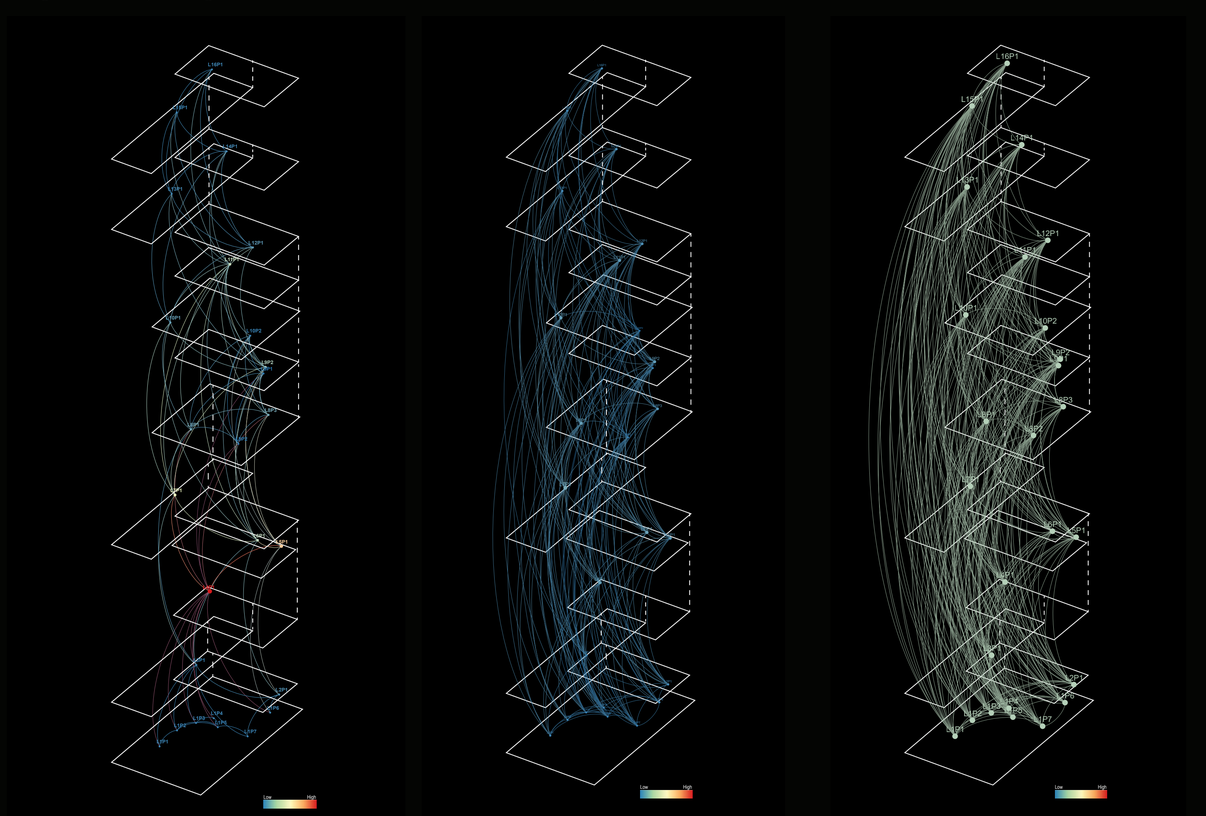

Figure 5a: Analysis diagrams - 25m, 50m, 100m Betweenness Centrality Network

DISCUSSION

- **Degree Centrality**

In general, the average node connectivity in Wilmar was found double the average of Solaris, indicating that overall, the potential for movement of terrestrial species within Wilmar is relatively higher than Solaris. L4 and L11 nodes in Solaris showed significant strength in degree centrality at 25m radius, indicating potential habitat hubs. L4 nodes in Wilmar showed maximum values for the same radius, while at 100m there were no significant variations between nodes. The average values in Wilmar were much higher than Solaris, thus as the radius increased, the degree centrality values also increased in Wilmar compared to reduction in values in Solaris.

- **Closeness Centrality**

The average values for closeness in Wilmar were much higher than Solaris, indicating that the networks in Wilmar were more comact with many nodes located in closer proximity to each other compared to Solaris. For 25 and 50m radius, there is visible differentiation in the node clustering, with L5P1 and L16P1 in Solaris and L1 and L4 standing out as the maximum clustered nodes. However for 100m radius, the differentiation disappears, with almost all nodes equally distributed in terms of closeness. Wilmar shows the potential to become a larger ecological habitat due to its higher average values.

- **Betweenness Centrality**

The average values of betweenness were visibly way higher in Wilmar compared to Solaris, and the proximity of high value nodes at the ground level plays a significant role in the improved connectivity at the elevated levels. As expected, the Wilmar nodes at L4, L5, L7 act as key connectors in the overall network in addition to the ground level nodes. In Solaris, while the nodes in L5 and L11 stand out for 25m radius, all nodes seem to have a failry even distribution within the network. The presence of large percentage of biodiversity attracting species in Wilmar play a key role in improving the ecological connectivity value of the elevated nodes.

Spatially Solaris has continuity and seamless connectivity in the elevated greenery. The nodes present potential opportunity to become better connected ecologically, by improving the node features and habitat provisioning potential. Increasing biodiversity attracting plants may significantly enhance its ecological connectivity performance. Wilmar, with its proximity to the park and with a rich biodiversity attracting plant pallette has the potential to function as a ecological node for the neighbourhood.

CONCLUSION

The results underscore the significance of vertically integrated green spaces as critical habitats for birds and pollinators, thus serving as vital components of urban ecological networks. The study provides quantitative results on the significance of adjacency to park space in the overall ecological performance of skyrise greenery. It validates that Wilmar building with its context has the potential to perforam as an ecological node as a whole, while Solaris with its isolated positioning has to rely on the enhanced biodiversity within the development to improve its ecological performance. The exploratory study highlights the significance of empirical mapping process and the definition of node and edge weights. The methodology and indicative results provide valuable base data for further validation of the actual performance on site. The framework also establishes a platform to further refine the node weights, explore ecosystems services contributions, and more importantly, scale up from a building or neighbourhood scale to larger districts. The study offers critical insights into the current discussion about urban sustainability and biodiversity conservation towards building a 'City in Nature'.

NEXT STEPS

- Validation of results to evaluate the accuracy and effectiveness of the network analysis through onsite biodiversity surveys
- Exploration of integrating a district level ecological connectivity study to include all the skyrise greenery with the ground level urban green open spaces

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