CHAPTER 8
Eco-Link@BKE: Restoring for Connectivity

Sharon Chan, Sunia Teo, Chong Han Wei, Chung Yi Fei & Cheryl Chia

Background
The 11-kilometre Bukit Timah Expressway (BKE) was completed in 1986 to facilitate the flow of vehicular traffic to the north of Singapore, easing congestion for residents living along Bukit Timah Road. Its construction divided a once continuous patch of rainforest, the Central Nature Reserve, into two separate forested areas – Bukit Timah Nature Reserve and Central Catchment Nature Reserve. This had consequences for the native flora and fauna of the rainforest.

The BKE became a physical barrier separating the two Nature Reserves, isolating habitats and populations. Most endangered species of forest wildlife are elusive in nature, and avoid human disturbances such as major roads. With populations of these animals thus isolated from each other by the six-lane BKE, inbreeding depression, which is the reduced biological fitness in a population due to breeding of related individuals, is likely to occur and could lead to their local extinction.

However, being situated between the two forests, the BKE inevitably led to the increased occurrences of vehicle-wildlife collisions. Between 1994 and 2014, there were two Sunda Pangolin (*Manis javanica*) deaths on major roads around the nature reserves. This species of pangolin is classified as critically endangered on the International Union for Conservation of Nature Red List of Threatened Species. Other common roadkill include the Common Palm Civet (*Paradoxurus hermaphroditus*), Long-tailed Macaque (*Macaca fascicularis*), and a number of reptile species.

Objectives of building the Eco-Link@BKE
A feasibility study of the wildlife road crossing project was conducted, to determine the possible locations and the concept design of the link between the two reserves. Taking into consideration the wildlife in the vicinity and the natural landscape of potential locations, it was decided that a wildlife bridge overpass built over the BKE was a better option than a wildlife viaduct. A wildlife overpass would result in less impact on traffic flow on the expressway, cause less unmitigated noise, and produce in a smaller environmental footprint. The wildlife overpass that was conceived in 2013 is now known as the Eco-Link@BKE.

The Eco-Link@BKE is one of Singapore's efforts to address fragmentation by habitat restoration, hence, facilitating biodiversity conservation in our urban landscape. The key objectives of the Eco-Link@BKE were:

1) reinstating the connectivity between two Nature Reserves, Singapore's largest primary and secondary forests,
2) documenting the animals that reside at these sites that would potentially use the Eco-Link@BKE,
3) documenting the changes in species composition, and
4) investigating the population trends of the target species – pangolin, mousedeer, wild boar, and deer – in the vicinity of the bridge.

The Eco-Link@BKE would be the first overhead ecological corridor to be built in the region. Shaped like an hourglass, it would be widest at both ends and tapered towards the centre of the bridge, which would be 50 metres wide at its narrowest. When completed, it would enable animals, birds, and insects to move freely along the connecting bridge, allowing for the effective exchange of native plant and animal genetic materials between the two nature reserves. In the longer term, the Eco-Link@BKE would help restore the ecological balance in these fragmented habitats and provide a conducive environment for our biodiversity to thrive.

The target species for the Eco-Link@BKE included terrestrial mammals with restricted home ranges, species with a higher incidence of roadkill, and threatened species such as the Sunda Pangolin, Common Palm Civet, and Lesser Mousedeer (*Tragulus kanchil*). Disturbance-sensitive forest birds, insectivorous bats, and other invertebrates were also projected to benefit from the construction of the Eco-Link@BKE.

Prior to the construction of the Eco-Link@BKE, biodiversity monitoring surveys were carried out by nature groups, tertiary institutions, government agencies working closely with National Parks Board (NParks), to collect baseline data for future comparison and assessment. Camera traps and nocturnal faunal surveys also recorded several rare and geographically restricted mammals, including the Lesser Mousedeer and Sunda Pangolin. Forest birds such as barbets, babblers, and bulbuls were also observed in the vicinity of the proposed site of the Eco-Link@BKE. These species are vulnerable to local extinction and would not cross the expressway without a wildlife bridge.

Site selection and utilisation

The site selection was crucial for minimising land clearance. Although the BKE drove through the forests between BTNR and CCNR, the natural landscapes were maintained with knolls and valleys. Based on the topography of the area, an overhead eco bridge was planned to be at a site with two knolls on either side of the expressway (Fig. 1).

Fig. 1. Location of the Eco-Link@BKE.

To ensure undisrupted traffic flow and minimise the footprint of the construction, effective site utilisation was highly emphasised (Fig. 2). The construction maximised the use of precast technology while stringent earth control measures were implemented.

Fig. 2. The traffic flow along the BKE was maintained throughout the construction phase, while the inconvenience for the commuters along BKE was minimised.

Landscape concept plan

The landscape concept for the wildlife bridge was a lowland forest habitat which would have great value both as a habitat as well as for wildlife. This habitat would have three key layers where the upper layer would be all tall trees while the lower level would be made up of saplings of several species. The ground vegetation would often be sparse and comprise mainly small trees and shrubs. By replicating these habitats in the bridge, it would be able to serve as a conducive corridor for wildlife by providing food, cover, and protection to many different animals, including small mammals, birds, and many insects.

The bridge was designed to withstand the weight of more than two metres depth of soil and tropical trees. The skyrise greenery concept guided us on the soil depth and soil type to be introduced on the bridge. The backfilling materials consisted of 10 different layers (Fig. 3). The top soil and the loamy soil were the major components of the backfilling materials which included a geogrid to help anchor the roots. These two layers would hold certain level of water and support the tropical plant to be grown on the bridge. To prevent additional weight caused by waterlogging, a gentle gradient was created at the base of the bridge, so that the water infiltrated through the soil would be discharged down the bridge into the storm drain.

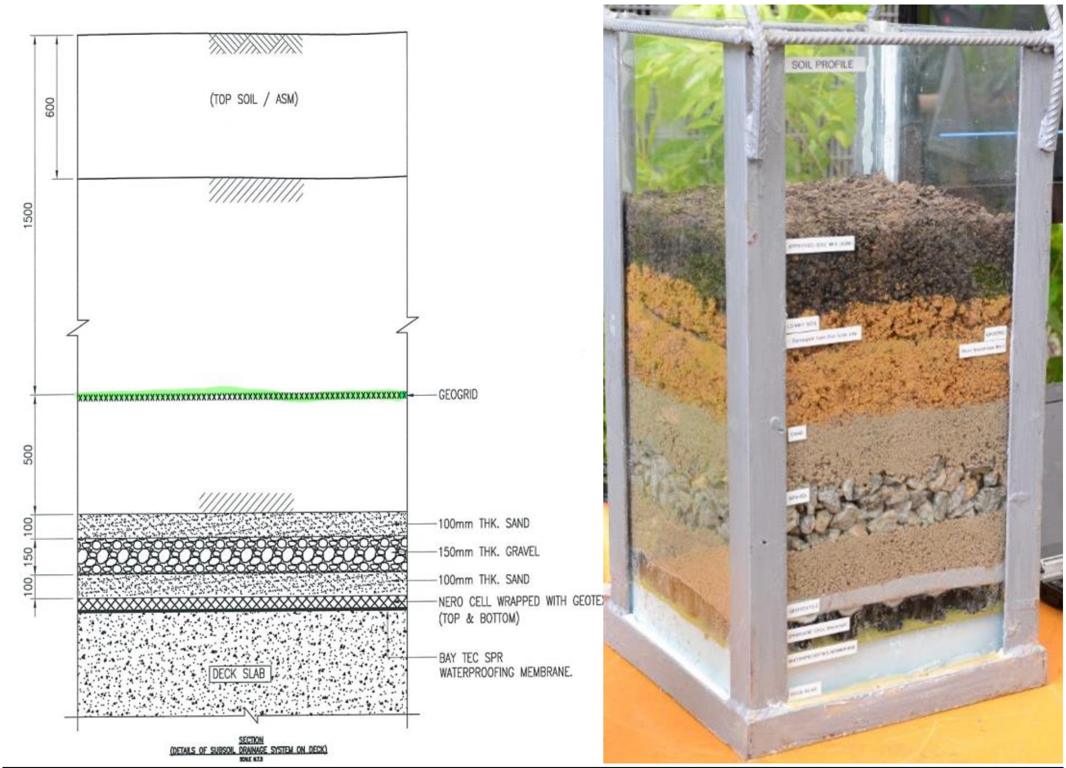
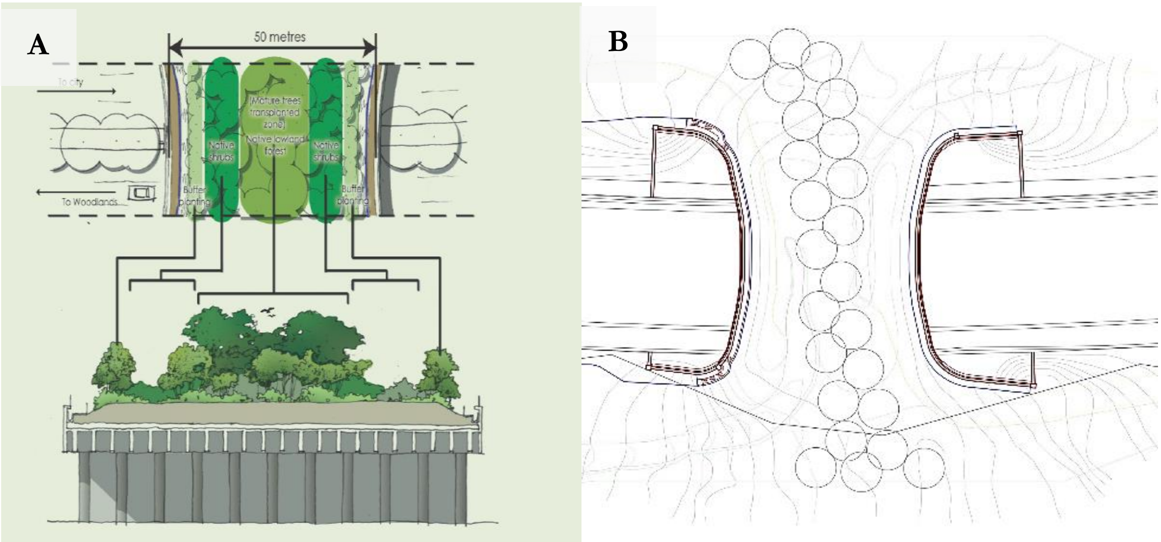


Fig. 3. A diagram and a model showing the soil profile on the Eco-Link@BKE. From top to bottom, the layers are top soil, loamy soil, geogrid, loamy soil, sand, gravel, sand, geotextile, drainage cell, and water proofing membrane.

Before the establishment of the greenery, the weather conditions on the bridge were very harsh with high sunlight intensity, high wind speed, low humidity, and high ambient temperatures. The pioneer native plants were carefully selected based on the characteristics, such as tolerance to extreme conditions on the bridge, provision of food and shelter, and hardiness. Some of the species that successfully established on the bridge were Elephant Apple (*Dillenia indica*)*,* Petai (*Parkia speciosa*), Sandy-leafed Fig (*Ficus heteropleura*)*,* Singapore Rhododendron (*Melastoma malabathricum*)*,* Campanula Orchid (*Dianella ensifolia*)*,* Cane Reed (*Cheilocostus speciosus*) and others.

In general, more shrubs were planted at the edge to create a barrier between the interior and the disturbed edges while most of the taller forest trees were planted in the middle that formed the backbone of the landscape ecosystem (Fig. 4). More than 3,000 native plants were used to lay the foundation of a seamless forest between the two nature reserves across the Eco-Link@BKE.



Figs. 4. (A) General planting plan of the Eco-Link@BKE where hedging created by shrubs minimise disturbances on the interior, and the trees were planted in the middle; (B) Diagram showing the gradient of the soil and proposed locations of the big trees.

To reduce competition from weeds and tall grass, grass cutting was scheduled every two weeks. This ensured that the fast-growing turf grass would not compete with the young native plants for nutrients. Strict maintenance regime was crucial for the early succession and establishment of the native plants.

Many lower quality habitats within the reserves and in the vicinity of the Eco-Link@BKE were also reforested to speed up the regenerating process. The different stages of the building of the Eco-Link@BKE and the progressive maturing of the ecosystem restoration from April 2013 to 2019 are shown in Fig. 5 to 8.

Figs. 5. Aerial photographs of the Eco-Link@BKE project taken in (A) April 2013 and (B) August 2013.

Figs. 6. Aerial photographs of the Eco-Link@BKE project taken in (A) November 2013 and (B) June 2014.

Fig. 7. Aerial photograph of the Eco-Link@BKE project taken in 2017.

Fig. 8. Aerial photograph of the Eco-Link@BKE project taken in 2023.

Species monitoring

While there were no pre- and post-development studies carried out on the effects of the BKE on the fragmentation of the two reserves, it was widely accepted that smaller fragments of forests supported fewer species and would degenerate over time and thus unable to support forest specialist species in the long term, based on studies in other places. Connecting the two fragments would, undoubtedly, have a positive impact on the biodiversity in both reserves. However, detailed and long-term monitoring studies would need to be in place to ascertain the effectiveness of the link for various groups of animals so that appropriate measures could be determined based on sound science. The monitoring data would assist in determining which target animal groups were not crossing the link and would prompt us to explore alternative ways to improve ecological connectivity in the future.

The use of camera traps began in 2011, to document and monitor the animals that would benefit from the construction of the Eco-Link@BKE. The native animals in Singapore's nature reserves were shy, cryptic, and nocturnal. This meant that intensive human resources were required if "traditional" forms of sampling such as line transects, visual surveys and pitfall traps were adhered to. Camera traps were a non-intrusive way to study and monitor the movement of animals. By employing camera traps, surveyors were able to minimise disturbances, entering the forest only during deployment and retrieval. The camera trap, once deployed, would continuously capture any movement of animals in its visual path.

For this study, three sites were identified: one in Bukit Timah Nature Reserve, one in Central Catchment Nature Reserve and one in Chestnut. The first two sites were identified as habitats that would benefit directly from the Eco-Link@BKE, while the third one was identified as the control site. These three sites were surveyed five times, in three different monitoring events (Table 1).

Table 1. Schedule of the five survey years and their respective monitoring events

Year	Monitoring event
2011 & 2012	Pre-construction monitoring
2015	Post-construction monitoring
	Pre-habitat enhancement monitoring
2018 & 2021	Post-habitat enhancement monitoring

By deploying camera traps at pre-determined Global Positioning System (GPS) coordinates, we were able to monitor not only the animals' presence during the survey year, but could also perform analysis of the long-term monitoring results.

Conclusion

The fauna survey of terrestrial vertebrates, birds and butterflies recorded an impressive species list on the Eco-Link@BKE. In total, more than 101 different faunal species were sighted in this human-made ecological overpass. This could be attributed to the intensive re-wilding of the bridge by planting native plants in a stratified layer, which had attracted other ecosystem engineers as well – the butterflies and the birds. Hence, it was important to record the species richness on the bridge to better understand the ecological succession process.

This project highlighted the importance of a long-term monitoring research project that allowed researchers to track the species detection changes over the years. Species of interest such as the Sunda Pangolin (Fig. 9 & 10) and Lesser Mousedeer (Fig. 11) could be monitored to assess the effectiveness of the bridge with respect to each species and the results can hence inform the relevant, important management decision to ensure the population could be sustained on a long-term basis. A 30-day deployment regime and alternate year monitoring provided a sufficient sampling method that could be easily replicated for long term monitoring.

The alternative year constant monitoring could be employed by environmental impact assessment/biodiversity impact assessment studies in order to chart a more accurate qualitative and quantitative biodiversity study for their field evaluation. Hence, planners and land-owners would be able to make more informed decisions of their land use and management plans based on sound science.

Based on the regular monitoring records of the Eco-Link@BKE, which has been established for at least ten years, we have achieved our mission of conserving native biodiversity, in particular, the rare forest-dependent species, and ensuring that they would be able to thrive in an urban biophilic city like Singapore.

Fig. 9. A camera trap captured a Sunda Pangolin (bottom left) crossing the Eco-Link@BKE in 2018.

Fig. 10. A camera trap captured a Sunda Pangolin crossing the Eco-Link@BKE in 2021.

Fig. 11. A Lesser Mousedeer was captured in front of the camera trap at the Eco-Link@BKE.